UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Exploring the integration of smartboard affordances with pedagogy when teaching photosynthesis to grade 11 learners

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Research Report submitted in fulfilment for the ***MASTER OF EDUCATION*** *degree*

Johannesburg, South Africa

25 September 2025

Abstract

This study investigated the integration of smartboard affordances, a prevalent Information and Communication Technology (ICT) tool, within Grade 11 Life Sciences classrooms in Gauteng, South Africa, specifically focusing on the teaching of photosynthesis. Despite the widespread adoption of smartboard affordances, research indicates a disconnect between their presence and pedagogical practices. Employing a qualitative approach, this research explored how teachers integrated smartboard affordances with established pedagogical methods, utilizing the SAMR (Substitution, Augmentation, Modification, Redefinition) model and the Refined Consensus Model of Pedagogical Content Knowledge (PCK) for analysis. Data was collected through collaborative lesson planning, interviews, classroom observations, and video recording across three secondary schools.

The findings revealed that to integrate smartboard affordances into grade 11 photosynthesis instruction, teachers should start by deeply analysing the content knowledge to determine its best representation, then select pedagogical strategies aligned with the content and diverse learning styles, while also considering their knowledge of learners and the learning environment to foster a rich and engaging experience.

Challenges such as inconsistent electricity supply and technical malfunctions were identified, underscoring the necessity for resilient teaching strategies. The study concludes that successful smartboard affordances integration requires a shift from passive utilization to interactive, learner-centred approaches, facilitated by ongoing professional development and Gauteng Department of Education support. It emphasized the collaborative use of the SAMR and PCK models to provide an understanding of the teaching process. This research offers valuable insights for teachers seeking to leverage smartboard affordances to enhance teaching and learning in the digital age, advocating for pedagogical innovation and continuous improvement.

Keywords: *Refined Consensus Model of PCK, SAMR Model, smartboard affordance, photosynthesis.*

Declaration

I, Ritha Mazibuko, confirm that the research study titled "**Exploring the integration of smartboard affordances with pedagogy when teaching photosynthesis to grade 11 learners.**" is entirely my original work. I have not submitted it for assessment in any other academic program or institution. I have properly acknowledged all external sources that I have used through citations and a reference list. I am aware that the University of the Witwatersrand will impose disciplinary measures if it is discovered that this is not my work or that I have failed to provide adequate citation of any ideas or words I used.

Signature:

Date: 7 April 2025

Acknowledgements

Throughout my research, I was fortunate to receive immense support and encouragement. First and foremost, I offer my deepest gratitude to God, the ultimate source of strength, for enabling me to complete this study. I am profoundly thankful to my supervisor, Professor Eunice Nyamupangedengu, for her exceptional guidance, patience, and insightful feedback, which significantly enhanced the quality of my work.

I extend my sincere appreciation to my colleagues, Sinothile Magwaza and Prudence Zimba, from the Science and Technology Department at Wits School of Education, for their unwavering support throughout this journey.

My heartfelt thanks go to my mother, Amukelani Mazibuko, for her invaluable advice, compassionate presence, and constant belief in my potential. Her unwavering support has been a continuous source of inspiration. I am also grateful to my siblings, Sonto Mazibuko, Bongani Mazibuko, and Lucky Shabalala, for their assistance throughout the year. My nephew, Awonke Lethokuhle Zondo, brought light, joy, and happiness to my life.

Finally, I want to acknowledge my friends, Nonhlanhla Ann Mahlangu, Helen Khoza, and Lydia Chauke for always being there when I needed you. Your collective support was crucial to the completion of this research, and I am deeply grateful for your contributions.

Dedication

This research is dedicated to my mother, Amukelani Mazibuko. Her unwavering strength and belief in me, even when I doubted myself, were my constant support. Thank you for always encouraging me to realize my full potential. Your prayers and constant reminders that anything is possible with God have been the foundation of my success. Without your faith and guidance, and without God, this accomplishment would not have been possible.

Table of Contents

Abstract i

Declaration ii

Acknowledgements iii

Dedication iv

List of Abbreviations ix

List of Tables x

List of Figures xi

List of Appendices xiii

Chapter 1 1

Introduction to the study 1

1.0 Introduction 1

1.1 Background and context of the study 1

1.1.1 Smartboards/Interactive whiteboards and smartboard affordances 2

1.1.2 Teaching and learning of photosynthesis 3

1.1.3 Teaching grade 11 learners' photosynthesis 3

1.1.4 Smartboard affordances integration with pedagogy. 4

1.2 Rationale of the study 5

1.3 Research problem 6

1.4 Purpose of the study 7

1.5 Research questions 7

1.5.1 Primary question 7

1.5.2 Secondary questions 7

1.6 Research objectives 8

1.7 Definitions 8

1.8 Chapter outline 8

1.9 Conclusion 9

Chapter 2 10

Literature Review and Conceptual Frameworks 10

2.0 Introduction 10

2.1 Teaching and learning 10

2.2 ICT and ICT integration with a specific focus on smartboard affordances 11

2.3 Smartboard as an ICT tool 12

2.4 Teachers' pedagogical practices when teaching using smartboard affordances. 13

2.5 Teaching practices in integrating smartboard affordances with pedagogy. 16

2.6 Integrating smartboard affordances with pedagogy to teach photosynthesis and other topics in grade 11. 17

2.6.1 What is photosynthesis? ... 17
2.6.2 Why photosynthesis? ... 17
2.6.3 What literature says about the teaching and learning of photosynthesis ... 18
2.6.3.1 Difficulties encountered during the teaching and learning of photosynthesis ... 19
2.6.3.2 Photosynthesis misconceptions ... 19
2.7 Integration of smartboard affordances with pedagogy when teaching photosynthesis ... 20
2.8 The gap in integrating smartboard affordances with pedagogy. ... 21
2.9 Findings from other researchers on the use of smartboard affordances in the classroom. 22
2.10 Conceptual frameworks for the study ... 23
2.10.1 The Refined Consensus Model of PCK ... 23
2.10.2 The Substitution, Augmentation, Modification, and Redefinition (SAMR) Model ... 28
2.11 Conclusion ... 30
Chapter 3 ... 32
Research Design and Methodology ... 32
3.0 Introduction ... 32
3.1 Research method ... 32
3.2 Research paradigm ... 32
3.3 Research design ... 33
3.4 Participants: Participating schools, teachers and the researcher ... 33
3.4.1 Research Sites ... 34
3.4.1.1 School 1: Suburban Semi-Public School ... 34
3.4.1.2 School 2: Township Government School ... 34
3.4.1.3 School 3: Township Government School ... 34
3.5 Data collection method ... 38
3.5.1 Lesson planning ... 40
3.5.2 Semi-structured interview ... 44
3.5.3 Participant observation ... 45
3.5.4 Video recording ... 47
3.6 Visiting the three schools. ... 48
3.7 Data analysis ... 50
3.7.1 Coding and theme identification ... 50
3.7.2 Narratives Enquiry ... 51
3.7.2.1 Development of narratives ... 51
3.7. 3 Reflective Analysis ... 53
3.8 Establishing rigor ... 53
3.9 Ethical consideration ... 55
3.10 Conclusion ... 55

Chapter 4 ... 56

Findings and discussions ... 56

4. Introduction ... 56

4.0 Data analysis and presentation of findings ... 57

4.1 Analysis of transcripts of prior lesson planning process interviews. ... 57

4.1.1 Narratives from the interview with teacher Jade. ... 58

4.1.2 Narratives from the interview with teacher Samantha. ... 59

4.1.3 Narratives from the interview with teacher Zandaya. ... 60

4.1.4 The importance of conducting the interview prior the collaborative lesson planning process. ... 61

4.2 Results from the analysis of the collaborative lesson planning process. ... 64

4.2.1 Insights drawn from Collaborative Lesson Planning and Teacher Oversights ... 66

4.2.2 Pedagogical approaches that the researcher and the three participating teachers agreed upon during the collaborative lesson planning process. ... 68

4.2.3 Smartboard affordances that the researcher and the participating teachers agreed upon during the collaborative lesson planning process. ... 70

4.2.4 Oversights and Missed Opportunities drawn from Collaborative Lesson Planning. ... 71

4.2.5 The importance of collaborative lesson planning. ... 71

4.3.1 Insights drawn from the narratives derived from a video recording of the first lesson from school 1 ... 73

4.3.2 Insights drawn from the narratives derived from a video recording of the first lesson from school 2 ... 77

4.3.3 Insights drawn from the narratives derived from a video recording of the first lesson from school 3 ... 79

4.3.4 Refined consensus model of PCK and SAMR as lenses: Analysing Smartboard Implementation and Progression in Three School Settings. ... 82

4.4.1 Insights drawn from the narratives derived from listening to audio recordings from interview conducted after the first lesson was taught at school 1. ... 85

4.4.2 Insights drawn from the narratives derived from listening to audio recordings from interview conducted after the first lesson was taught at school 2. ... 86

4.4.3 Insights drawn from the narratives derived from listening to audio recordings from interview conducted after the first lesson was taught at school 3. ... 87

4.5.1 Insights drawn from narratives derived from watching and analysing video recordings from the second lesson from school 1. ... 88

4.5.2 Researcher's reflection on the lesson she delivered at school 1. ... 92

4.5.3 Insights drawn from narratives derived from watching and analysing video recordings from the second lesson from school 2. ... 93

4.5.4 Researcher's reflection on the lesson she delivered at school 2. ... 96

4.5.5 Insights drawn from narratives derived from watching and analysing video recordings from the second lesson from school 3. ... 98

4.5.6 Researcher's reflection on the lesson at school 3. ... 101

4.6.1 Narratives drawn from listening to feedback session derived from the second lesson taught at School 1. 104

4.6.2 Narratives drawn from listening to feedback session derived from the second lesson taught at School 2. 105

4.6.3 Narratives drawn from listening to feedback session derived from the second lesson taught at School 3. 106

4.7 Overall insights on how to integrate smartboard affordances drawn from the analysis of interview transcripts. 108

4.8 Overall oversights and missed opportunities drawn from the analysis of the interview transcripts. 109

4.9 Overall insights on how to integrate smartboard affordances drawn from the analysis of video transcripts. 109

4.10 Overall oversights and missed opportunities drawn from the analysis of video transcripts. 110

4.11 Building on PCK: Aligning Smartboard Affordances with SAMR Model for Transformative Learning Experiences. 110

Chapter 5 114

Conclusion, Recommendations, Limitations of the study and Implications of the study 114

5.0 Introduction 114

5.1 Summary of the study 114

5.1.1 The extent on which the teachers integrated smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners. 115

5.1.2 Steps that teachers can follow to integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners. 116

5.2 Challenges faced by teachers when integrating smartboard with pedagogy. 119

5.3 Implication of the study 119

5.4 Limitations of the study. 120

5.5 Recommendations of the study/ Suggestion for future research 121

5.6 Conclusion: Final statement on the significant of the study 122

6. References 123

List of Abbreviations

A-	Augmentation
AK-	Assessment Knowledge
ATP-	Annual Teaching Plan
CAPS-	Curriculum Assessment Policy Statements
CUR-	Curricular Knowledge
cPCK-	Collective PCK
CK-	Content Knowledge
ePCK-	Enacted PCK
ICT-	Information and Communication Technology
KL-	Knowledge of the Learners
M-	Modification
PCK-	Pedagogical Content Knowledge
PK-	Pedagogical Knowledge
pPCK-	Personal PCK
R-	Redefinition
S-	Substitution
SAMR-	Substitution, Augmentation, Modification, Redefinition

List of Tables

Table 1: A summary of the smartboard affordances that can be used by teachers.

Table 2: A summary of participating schools and their context.

Table 3: A summary of participating teacher's biography.

Table 4: A summary of the smartboard affordances selected during the planning process.

Table 5: A summary of the interviews conducted in three schools

Table 6: A summary of lessons observed by the researcher and taught by the researcher

List of Figures

Figure 1: A summary of refined consensus model of PCK

Figure 2: A summary of SAMR Model.

Figure 3: School 1 classroom.

Figure 4: School 2 classroom.

Figure 5: School 3 classroom.

Figure 6: Notes from lesson planning from the 6th of June 2024.

Figure 7: Notes taken from lesson planning from the 29th of August 2024.

Figure 8: Notes taken from lesson planning from the 29th of August 2024 on Mentimeter.

Figure 9: A summary of how data was collected.

Figure 10: The order of data analysis and findings

Figure 11: CAPS document displaying content that must be taught to the learners.

Figure 12: ATP displaying content that must be taught to the learners.

Figure 13: A picture of trees that the researcher and the participating teachers agreed to use to elicit learners' prior knowledge.

Figure 14: ATP displaying prior knowledge from previous grades.

Figure 15: A picture of green plants, selected by the researcher and the three participating teachers to connect the lesson to real-world experiences for the learners.

Figure 16: A QR Code which, when scanned, leads to a multiple-choice topic test on photosynthesis. This test was designed collaboratively by the researcher and the three participating teachers and was scheduled for learners at the end of the first lesson.

Figure 17: Pictures that were agreed upon by the researcher and the three participating teachers to show the learners the equipment needed to conduct the starch test.

Figure 18: Biological terms that Jade was teaching the learners through annotation.

Figure 19: Pictures displaying the requirements of photosynthesis.

Figure 20: Learner doing corrections on the smartboard through writing and annotation.

Figure 21: Samantha annotating on the smartboard.

Figure 22: An example of visual aids used by Zandaya to show the learners a structure of a chloroplast.

Figure 23: A learner drawing a diagram of a chloroplast and labelling it with the help of her classmates.

Figure 24: A screengrab from video recording where the researcher is showing learners pictures of laboratory attires.

Figure 25: Learner's anonymous responses on Mentimeter.

Figure 26: The connection between Refined Consensus Model of PCK and SAMR Model.

Figure 27: A summary of a sequence that teachers can follow to integrate smartboard affordances with pedagogy to teach photosynthesis.

List of Appendices

The analysis employed a deductive coding approach, where different colours were assigned to represent specific theoretical constructs within the Refined Consensus Model of PCK and the SAMR model. The coding scheme was as follows: yellow was used to identify instances of collective PCK , indicating a teacher's integrated knowledge of subject matter and teaching strategies. Green codes represented enacted PCK, capturing instances where this knowledge was put into practice within the classroom. Blue codes were assigned to personal PCK, reflecting the teacher's individual beliefs and experiences that shape their teaching. Additionally, purple codes were used to identify instances of the SAMR model, signifying how the technology was being integrated, whether for substitution, augmentation, modification, or redefinition.

APPENDIX 1: Wits Ethical Clearance Letter

APPENDIX 2: Approval Letter from Gauteng Department of Education

APPENDIX 3: Information Letter for Principals

APPENDIX 4: Information Letter for Teachers and Consent Forms

APPENDIX 5: Information Letter for Parents and Consent Forms

APPENDIX 6: Information Letter for Learners and Assent Forms

APPENDIX 7: Lessons Observational Tool

APPENDIX 8: Lesson Observational Transcripts from school 1 for lesson 1.

APPENDIX 9: Lesson Observational Transcript from school 1 for lesson 2.

APPENDIX 10: Lesson Observational Transcript from school 2 for lesson 1.

APPENDIX 11: Lesson Observational Transcript from school 2 for lesson 2.

APPENDIX 12: Lesson Observational Transcript from school 3 for lesson 1.

APPENDIX 13: Lesson Observational Transcript from school 3 for lesson 2.

APPENDIX 14: Semi-structured Interview Questions

APPENDIX 15: Semi-structured Interview Transcript: School 1 before collective lesson planning process.

APPENDIX 16: Semi-structured Interview Transcript: School 1 after lesson 1.

APPENDIX 17: Semi-structured Interview Transcript: School 1 after lesson 2, Feedback session.

APPENDIX 18: Semi-structured Interview Transcript: School 2 before collective lesson planning process.

APPENDIX 19: Semi-structured Interview Transcript: School 2 after lesson 1.

APPENDIX 20: Semi-structured Interview Transcript: School 2 after lesson 2, Feedback session.

APPENDIX 21: Semi-structured Interview Transcript: School 3 before collective lesson planning process.

APPENDIX 22: Semi-structured Interview Transcript: School 3 after lesson 1.

APPENDIX 23: Semi-structured Interview Transcript: School 3 after lesson 2: Feedback session.

APPENDIX 24: Sample of CAPS document

APPENDIX 25: Sample of ATP

APPENDIX 26: Lesson Planning Notes.

Chapter 1

Introduction to the study

1.0 Introduction

This chapter introduces a study examining the integration of smartboard affordances with pedagogy in teaching photosynthesis to Grade 11 learners in Gauteng, South Africa. It establishes the background by defining smartboards and their affordances, highlighting their potential for interactive learning, particularly for complex topics like photosynthesis. The chapter discusses the challenges of utilizing smartboards, citing issues such as underutilization and a lack of pedagogical integration, despite teachers possessing technical skills (Pourciau, 2014). The study aims to identify effective steps for integrating smartboard affordances into photosynthesis lessons and to explore the extent to which teachers currently implement them. It addresses the primary research question: How do teachers integrate smartboard affordances into photosynthesis lessons? Secondary questions include: What specific steps can teachers follow to integrate smartboards? And, to what extent are smartboards currently integrated into these lessons?

1.1 Background and context of the study

Kühl and Wohninsland (2022) define a smartboard as a large, touch-sensitive display designed for interactive presentations and teaching. This technology offers a range of affordances, notably the touch interface, which allows teachers to annotate directly on the screen. The use of varied colours facilitates creative thinking among learners, fostering active participation (Nishanthi & Ravindran, 2020). Specifically, smartboard affordances provide a toolkit that transforms traditional pedagogy. For instance, dynamic notetaking is achieved through annotation and highlighting, while more complex interactions, such as object manipulation and handwriting recognition, enhance instructional delivery (Bernát et al., 2020). Teachers can construct interactive lessons by layering content, revealing information sequentially, and duplicating objects. Furthermore, integrated tools, including timers and screen recording, improve classroom management and resource dissemination. Consequently, these diverse affordances empower teachers to develop dynamic, efficient, and engaging learning experiences (Bernát et al., 2020).

Furthermore, smartboard offer a multifaceted array of affordances that can be harnessed to develop greater adaptability and interactive experiences for both individual and collaborative teaching and learning processes (Mlambo et al., 2020). Therefore, learners would have the opportunity to respond with more enthusiasm and get out of their seats to learn more complicated topics (Nishanthi & Ravindran, 2020). However, despite the widespread installation of smartboards within South African classrooms, research suggests a disconnect between their presence in the classroom and demonstrably effective integration of the smartboard affordances with pedagogical methods (Mlambo et al., 2020). Therefore, this study seeks to explore how teachers integrate smartboard affordances with pedagogy when teaching photosynthesis in a grade 11 classroom at three secondary schools based in Gauteng province. The study further sought to find out if routines could be established that a teacher can follow to integrate smartboard affordances into their pedagogical practices.

Photosynthesis is one of the complicated topics in biology, it is widely recognized as the process by which plant chloroplasts utilize solar light energy and convert it into the chemical potential energy stored within the bonds of organic molecules (Karakaya et al., 2021). However, its inherent complexity presents a significant learning obstacle for many learners, often leading to rote memorization of individual steps and molecule names rather than fostering a deeper conceptual grasp of the interconnected nature of these processes (Wisner, 2022). This intricate biological concept poses a challenge due to its multifaceted nature, encompassing elements of chemistry, biology (encompassing both physiological and ecological aspects), and physics (Jančaříková & Jančařík, 2022).

Comprehending the complexities of photosynthesis requires a strong grasp of various scientific disciplines. As indicated by Wisner (2022), the molecular-level nature of the process challenges students, making it difficult for them to visualize and mentally represent the concepts (Wisner, 2022). Research suggests that incorporating smartboard features into photosynthesis lessons can facilitate interaction, boost learners' interest, and simplify the topic (Jammeh et al., 2022).

1.1.1 Smartboards/Interactive whiteboards and smartboard affordances

According to Nishanthi and Ravindran (2020) a smartboard is an ICT tool that functions as a whiteboard for the purpose of capturing written or typed data, modifying it, preserve and retrieve it later for integration with data from online sources or data that has already been saved to a drive. Hussein et al. (2022) further describes a smartboard in relation to education as a digital tool that functions as a large, touch-sensitive display connected to a computer, allowing for digital content manipulation and clear visibility for the entire classroom.

In addition to surfing the internet, modifying text and shapes, registering, and saving audio and video drills, smartboard affordances allow teachers and learners to write, draw, and save data, and send emails (Abdullah et al.,2020). In addition to this, displaying colourful visuals, animations, videos, and audios all contribute to how visually stimulating and enjoyable lessons may be (Mtshali, 2021). Therefore, smartboard affordances may be used to offer lessons in tangible, graphical, and aural learning methods. While the terms interactive whiteboard and smart board are often used interchangeably, this study will exclusively employ the term smartboard for consistency and clarity.

1.1.2 Teaching and learning of photosynthesis

Photosynthesis is recognised as one of the most demanding subjects in life sciences since it requires both learners and teachers to understand chemistry, physics, and biology (encompassing both physiological and ecological aspects) (Jančaříková & Jančařík, 2022). Learners find this concept challenging due to its abstract nature (Bizimana et al., 2022). This implies that learners will require high cognitive level of scientific abstraction to understand photosynthesis. Teachers and learners have misunderstandings of photosynthesis which lead to misconceptions which are oppositions to the currently accepted scientific views (Jančaříková & Jančařík, 2022). Teachers at all educational levels must possess a great deal of pedagogical expertise to teach photosynthesis. Teaching learners about photosynthesis fosters the development of both scientific vocabulary and metacognitive skills. These acquired abilities can then be leveraged to enhance comprehension of other complex scientific concepts (Jančaříková & Jančařík, 2022).

1.1.3 Teaching grade 11 learners' photosynthesis

The Grade 11 participants were chosen for this photosynthesis study due to their established foundational knowledge. Previous exposure to photosynthesis in Grades 6 and 8 provides a necessary basis for advanced investigation, as outlined by the Department of Basic Education (2011). This grade level marks a shift from general science education to specialized study, requiring a move beyond rote memorization to understanding and practical application of complex biological processes, such as photosynthesis, as suggested by Mhlamvu-Zikhali (2010).

The selection of Grade 11 also reflects the critical juncture in their academic development. This period is vital for consolidating core concepts, like photosynthesis, to prepare for final examinations and future educational pursuits. Strengthening these concepts at this stage fosters the development of essential critical thinking and problem-solving skills necessary for analysing complex biological mechanisms, as highlighted by Jančaříková & Jančařík (2022). Teachers play a key role in cultivating independent learning, encouraging engagement with scientific literature and self-directed investigations, aligning with the CAPS document's focus on scientific inquiry (Department of Basic Education, 2011). Moreover, a robust understanding of fundamental biological processes at this stage can significantly influence future academic and career choices, particularly in STEM fields, as demonstrated by Lee et al. (2018).

1.1.4 Smartboard affordances integration with pedagogy.

The concept of smartboards originated in 1980, involving a computer connected to a touch-sensitive display, however, they were first used in education around the late 1990s (Hendawi & Nosair, 2020; Akar, 2020). The smartboard replaced the chalk and a blackboard in most schools during the technology revolution. Furthermore, smartboards significantly enhance pedagogical efficiency and efficacy within the classroom environment since they assist teachers to present content in a way that is easy for learners to grasp it (Ndwandwe et al.,2024).

Smartboards have become widely recognized as valuable tools for teaching and learning at all levels of education (Yadav, 2019). Smartboards present teachers with a diverse set of affordances, designed to enhance teaching and learning. To harness these affordances, such as the touchscreen and annotation features, teachers must possess a robust pedagogical foundation. As Shah and Campus (2021) articulate, pedagogy is the art and science of teaching, encompassing the strategic deployment of methods to facilitate learning.

This pedagogical understanding acts as the guiding force, enabling teachers to integrate the potential of smartboard affordances into meaningful educational experiences. Without a strong pedagogical framework, the technological capabilities of the smartboard remain underutilized, failing to translate into improved learning outcomes. For example, as study conducted by Ndwandwe et al. (2024) demonstrated the strategic integration of smartboard technology to enhance pedagogy across various lesson phases. To elicit prior knowledge, teachers employed diagrams and PowerPoint presentations, while elaboration involved multimedia resources like pictures and YouTube videos to expand understanding. During exploration, new concepts were introduced through circuit board demonstrations, dynamic PowerPoint presentations, YouTube videos, and interactive smart notebook drawings.

The enlightening phase utilized animations and diverse visuals to clarify concepts, and the explanation phase leveraged diagrams, videos, and presentations for effective concept delivery.

Lesson summaries in the enclosure phase incorporated YouTube videos and PowerPoint. To foster creative thinking, smartboards were used to design practical tasks and quizzes, which were then utilized in the evaluation phase. Engagement was achieved through interactive quizzes, YouTube videos, and question-and-answer sessions with smartboard features, while the exchange phase facilitated ongoing dialogue and feedback, allowing teachers to address misconceptions through varied teaching strategies and interactive activities on the smartboard.

In this sense, the goal of this research is to explore ways to include smartboard affordances when teaching the topic of photosynthesis to grade 11 learners. Reason for choosing a smartboard is that it is regarded as a technological tool that enhances science teaching and learning between learners and teachers while equipping teachers with the abilities needed to adjust to a technologically advanced world (Palanisamy & Sivakumar, 2020). Teachers can deal with challenges of transforming content into an understandable form and enhance their teaching skill thanks to the classroom smartboards.

The study is centred on smartboard affordances integration during the photosynthesis lesson since knowing photosynthesis is vital for understanding many other environmental links and occurrences (Jančaříková & Jančařík, 2022). For instance, there are links between respiration, the carbon cycle, food chain, energy flow, ecosystem and more. The link between the above-mentioned concepts is that in an ecosystem, plants take in carbon dioxide from the atmosphere and use it for photosynthesis and animals such as lions obtain carbon from plants by feeding from herbivores, lastly, when plants and animals respire, they release carbon dioxide into the atmosphere (Solomon et al., 2018). Teaching photosynthesis can also help learners learn vocabulary related to science and develop cognitively, both of which are vital abilities for learning other difficult life sciences topics (Jančaříková & Jančařík, 2022).

1.2 Rationale of the study

This study delves into the pedagogical integration of smartboard affordances within Grade 11 Life Sciences classrooms specifically focused on photosynthesis instruction. While acknowledging the widespread technological literacy among South African teachers and learners, this study highlights a critical gap: the ability to merge smartboard affordances with established pedagogical practices.

Despite the widespread availability of smartboards in South African schools and the general technological competence of both teachers and learners, there is a significant gap in how this technology is actually used in the classroom. My own experiences, both as a learner and as an observer, echo this issue: many teachers, including my own, often use smartboards as little more than a modernized chalkboard or a screen for projecting PowerPoint slides. In these cases, smartboard affordances are largely ignored, and the lessons remain rooted in traditional, teacher-centered methods.

This study aims to address this critical disconnect, particularly within Grade 11 Life Sciences classrooms during the photosynthesis topic. The goal is to investigate how to effectively merge the unique affordances of smartboards (e.g., interactive simulations, multimedia integration, collaborative tools) with established pedagogical practices to create a more dynamic and engaging learning experience. The existing body of literature confirms this problem, with numerous studies highlighting that while teachers may have a positive attitude toward smartboards, they often lack the specific skills and knowledge needed to fully harness their potential (e.g., Orhani, 2023 ;Gumede & Mavuru, 2025). This study seeks to go beyond simply acknowledging this gap by exploring practical strategies for integrating smartboard affordances to transform photosynthesis instruction from a traditional, memorization-based approach into an interactive, inquiry-based learning experience.

1.3 Research problem

Despite the potential of smartboards to transform classroom instruction, teachers frequently fail to leverage their full interactive capabilities. Research consistently shows that educators often limit smartboard use to displaying visual aids and basic drawings, neglecting more dynamic features (Korkmaz & Cakil, 2013; Momani et al., 2016). This limited application stems from a deficiency in both pedagogical and technical proficiency. Although many teachers possess basic technical skills, they tend to revert to traditional teaching methods, such as writing directly on the board or projecting static slides, instead of integrating interactive features like video and collaborative tools (Mokoena et al., 2022; Mashiteng, 2020). This approach essentially digitizes conventional practices, failing to capitalize on smartboard affordances to enhance learner engagement and comprehension.

This issue is particularly pronounced when teaching abstract and complex topics like photosynthesis. Traditional, passive teaching methods often hinder learner engagement and can lead to misconceptions (Mekonen & Kelkay, 2023). Therefore, there is a critical need for innovative teaching strategies that utilize smartboard affordances to create dynamic, learner-centered environments that can improve conceptual understanding, encourage critical thinking, and promote active learning (Jammeh et al., 2022; Susanti et al., 2024). The core of the problem lies in the gap between teachers' technical skills and their pedagogical knowledge. Even when teachers know how to operate a smartboard, they often lack the understanding of how to effectively integrate its affordances into their instructional practices (Tefo, 2021). This gap highlights the need for a research informed and contextually relevant approach to smartboard integration that teachers can easily implement to create meaningful, interactive learning experiences, thereby bridging the divide between technology and effective teaching methods.

1.4 Purpose of the study

The purpose of this study is to explore the pedagogical integration of smartboard affordances in teaching photosynthesis to Grade 11 Life Sciences learners. The study intends to identify and elaborate on strategies that teachers can use to move beyond traditional, passive uses of the smartboard and fully utilize its affordances. Through focusing on a complex and often misunderstood topic like photosynthesis, this research seeks to demonstrate how a strategic integration of smartboard affordances such as videos, annotations, can transform instruction from rote memorization into a dynamic, inquiry-based learning experience. In other words, the goal is to provide potential practical strategies for teachers to bridge the gap between their technological proficiency and pedagogical knowledge, thereby maximizing the educational potential of smartboards in science education.

1.5 Research questions

1.5.1 Primary question

The main question the study seeks to address is:

1. How do teachers integrate smartboard affordances with pedagogy when teaching photosynthesis in the grade 11 life sciences classroom?

1.5.2 Secondary questions

The following secondary research questions were developed to further organise the researcher's trajectory in addressing the main research question:

1. To what extent did the teachers integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?
2. What steps can teachers follow to integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?

1.6 Research objectives

The main objectives of the study are to:

- Explore the extent in which teachers integrate smartboard affordances with pedagogy in the teaching of photosynthesis.
- Identify possible routine/s that teachers must follow to integrate smartboard affordances with pedagogy to teach photosynthesis to grade 11 life sciences learners.

1.7 Definitions

This section provides the definitions of terms used for purposes of this study.

- **Smartboard affordances-** Smartboard affordances encompass the interactive capabilities enabled by the integration of a digital board, computer, and projector, allowing for dynamic, engaging learning experiences through touch-based manipulation of multimedia content (Uqba et al.,2024).
- **Integration of ICT-** ICT integration in education is the purposeful use of technology to make teaching and learning more engaging and effective. It involves using digital tools not just for the sake of it, but to truly enhance, complete, and support the learning process while keeping the core content and goals of the lesson intact (Maru et al.,2021). In this context, the specific ICT being referred to is a smartboard.
- **Pedagogy-** Pedagogy is a complex field that involves a range of teaching methods, grounded in learned principles, professional experience, and individual insights. Essentially, it's the art and science of teaching, shaped by both formal training and practical application (Kapur, 2020).

1.8 Chapter outline

Chapter 1: The introductory chapter began by providing foundational information, including the definition of smartboards and their affordances, and emphasizing their potential to enhance interactive learning. Subsequently, the chapter identified the research problem, which centered on the inadequate use of smartboard affordances and the absence of pedagogical integration, even though teachers possessed technical proficiency. The study intended to determine effective procedures for integrating smartboard affordances into lessons on photosynthesis and to examine the extent to which these procedures were presently being applied. The chapter explicitly stated the research aims and inquiries, which concentrated on the methods teachers used to integrate smartboard affordances, the precise actions necessary for successful integration, and the level of current integration practices.

Chapter 2: This chapter explored into existing research on smartboard affordances, pedagogical integration, and the teaching of photosynthesis, establishing a theoretical foundation. This study utilized established frameworks, namely the Refined Consensus Model of PCK and the SAMR model, to analyse the use of smartboard affordances in teaching photosynthesis, thereby creating a structured approach for the research.

Chapter 3: The research design and methodology chapter detailed the study's qualitative approach. It described the process by which participants were selected, ensuring they met the criteria for the research. Furthermore, it explained the data collection methods, which included lesson observations and interviews, providing an understanding of the teachers' practices. Finally, the chapter outlined the data analysis procedures, emphasizing the steps taken to maintain rigor and validity throughout the research process.

Chapter 4: This chapter presented the empirical findings related to the integration of smartboard affordances in photosynthesis lessons, followed by an in-depth discussion of those findings in relation to the research questions and conceptual frameworks.

Chapter 5: This chapter summarized the key findings, offered practical recommendations for teachers and basic department of education, acknowledged the limitations of the study, and suggested areas for future research.

1.9 Conclusion

In conclusion, this chapter has established the context for exploring the integration of smartboard affordances with pedagogy in teaching photosynthesis to Grade 11 learners. Despite the technological potential of smartboard affordances and their prevalence in classrooms, a gap exists between their presence and effective pedagogical application, particularly for complex topics like photosynthesis. This study aimed to identify practical routines and assess the extent of integration, addressing the central question of how teachers can integrate smartboard affordances with pedagogical strategies to enhance learning outcomes.

Chapter 2

Literature Review and Conceptual Frameworks

2.0 Introduction

The Refined Consensus Model of PCK, the Substitution, Augmentation, Modification, and Redefinition (SAMR) Model and the current body of research are the main topics of this chapter as they inform the exploration of how life sciences teachers can integrate smartboard affordances with pedagogy in the classroom. It commenced with a concise exposition of the core concepts of teaching and learning. Subsequently, the study looked closely at how well smartboard affordances work in real-world teaching situations. Specifically, it examined how these smartboard affordances impact the way teachers teach, and learners learn in grade 11 Life Sciences, focusing on the complex topic of photosynthesis. The study evaluated if and how the smartboard affordances are truly helpful in improving teaching methods, and if it smoothly blends with the existing way teachers approach their lessons. Essentially, it checked if the smartboard affordances make learning better, or if they just add another layer of complexity. This chapter further addressed the identified research gaps concerning the integration of smartboard with pedagogy and insights gleaned from prior studies on integrating smartboards with pedagogical approaches. Finally, it concludes with a discussion of the Refined Consensus Model of PCK, the SAMR Model and its implications for technology in education.

2.1 Teaching and learning

Teaching practice involves the practical implementation of pedagogical approaches and strategies within a classroom environment (Toptaş, 2023). Teaching is also referred to as the process of facilitating the acquisition of skills and information by individuals (Rajagopalan, 2019). It is also considered as both an art and a science meaning that it involves both creative and systematic aspects (Opara et al., 2023). As an art, it requires a teacher's imagination and skill to create engaging learning experiences. As a science, it demands a logical approach to planning and implementing instruction to achieve specific learning goals (Opara et al., 2023).

Learning is known as a process where learners actively build their understanding by engaging with the material. It is no longer seen as passively receiving information during lessons rather as an engaged process of generating knowledge (Fagan, 2020). Furthermore, Ferreira et al. (2019) posit that learning is an ongoing process where individuals actively construct knowledge while simultaneously developing personally. This dynamic process is significantly influenced by an individual's goals, emotions, and internal motivations, highlighting the complex interplay between cognitive, emotional, and personal factors in learning. Deliberate interactions between educators, learners, resources, and environmental elements form a dynamic, linked system of learning that demands careful pedagogical judgements to maximise the outcomes of learning (Fatmawati & Rustaman, 2020).

2.2 ICT and ICT integration with a specific focus on smartboard affordances

ICT is an abbreviation for information and communication technology. It refers to a broad set of technological tools and resources used for communication as well as information generation, dissemination, storage, and administration (Das, 2019). It is related to information technology (IT), but it is more focused on communication technologies. According to Singh (2021), within the domain of ICT resides a diverse assemblage of technological apparatuses and resources. Extending from the ubiquitous presence of radio and television to the intricate networks governing cellular phones and computers. Furthermore, ICT constitutes a framework facilitating communication as well as the production, dissemination, storage, and management of information.

Conversely, the intentional and pedagogically sound integration of ICTs within the educational domain can be defined as the strategic utilization of various technological resources as well as tools to augment and enrich the teaching and learning processes. This encompasses a dynamic interplay between teachers, learners, and technology, fostering interactive, collaborative, and learner-centred experiences (Shah, 2022). ICT integration in the classroom can be further described as the strategic and impactful utilization of technology across all facets of the educational ecosystem. This encompasses the foundational infrastructure, the defined curriculum, and the diverse teaching and learning environments employed (Champa et al., 2021).

In a dynamic environment of constantly changing technological advancements, the thoughtful integration of ICT has the potential to play a mediating role in supporting successful instructional techniques used by teachers, ultimately fostering the cultivation of meaningful learning experiences for learners (Razak et al., 2019). According to Belouahem (2020) meaningful learning occurs when new information is purposefully assimilated into a learner's pre-existing schema. Integrating technology in education connects new information to existing knowledge, solidifying understanding, and creating a stronger foundation for learning. Therefore, the integration of smartboard affordances into methodologies like displaying animation features in the form of images and videos for teaching has demonstrably enhanced the efficiency of teaching and learning (Issa, 2020). This leads to improved learner academic performance and fostering effective educational management across various educational institutions (Belouahem, 2020). Furthermore, research suggests that ICT has facilitated increased participation among both teachers and learners on a global scale (Warioba et al., 2022).

Given the perceived potential of ICT as agents of substantial positive change, particularly in the realm of educational transformation and reform, the strategic integration of technology into instruction contexts may serve to not only facilitate the completion of tasks but also demonstrably enhance the efficacy of teachers in their endeavours to cultivate compelling and impactful pedagogical activities (Champa et al., 2021). Beyond merely incorporating ICT into the classroom, its strategic integration like displaying simulation videos has demonstrably enhanced learners' competency development. While ICT offer multifaceted tools to enhance the learning and teaching landscape, this study focuses into the pedagogical integration of one ICT tool: the smartboard affordances within the teaching domain.

2.3 Smartboard as an ICT tool

Within the educational landscape, ICT tools have emerged as ubiquitous facilitators of interaction, information generation, transmission, storage, and management (Belay, 2020). Among these tools, smartboards, also known as interactive whiteboards, have gained traction in life sciences classrooms. Research by Yalım (2021) suggests that smartboards use have demonstrably enhanced learner comprehension, time management skills, and enjoyment of learning within this context. Furthermore, Khosa and Molotsi (2020) highlight the positive impact of smartboards use on learner performance, attributing it to the increased active participation and heightened attention levels they foster in the classroom setting.

Smartboard is defined as a large, interactive display surface that integrates digital and traditional modes of instruction. It facilitates collaborative learning activities through touch interactivity and enhances lesson delivery by incorporating pre-loaded educational visuals and pedagogical software applications (Khosa & Molotsi, 2020). The integration of smartboard affordances in educational settings fosters interactive learning for learners of all levels by enabling teachers to design engaging electronic activities that manipulate texts and images, thereby promoting a deeper understanding through multimedia elements (Karthigesu & Mohamad, 2020). Additionally, teachers that incorporate smartboard affordances, into their pedagogy can provide learners with a more memorable learning experience (Demirbilek, 2022).

As already mentioned, smartboards hold promise for improved learner engagement and a more learner-centred approach, but their success depends on interactive lesson design (Hussein et al., 2022). Therefore, teachers need to move beyond simple information delivery to incorporating collaborative activities and multimedia (Abdulrahaman et al., 2020). These boards can transform classrooms into environments where learners actively construct knowledge (Khosa & Molotsi, 2020). This shift, facilitated by the diverse multimedia elements of smartboards (Abdulrahaman et al., 2020), fosters deeper understanding and a more interactive learning experience (Mapumulo, 2023). Essentially, multimedia in education represents a paradigm shift from teacher-centred knowledge transmission to learner-centred knowledge construction, requiring a transformation in the teacher's role from content provider to facilitator (Bolaji & Jimoh, 2023). Smartboard affordances gives learners real-world examples, making learning more engaging and relevant. Teachers can also feel confident that they are using a valuable tool to enhance their teaching (Issa, 2020).

2.4 Teachers' pedagogical practices when teaching using smartboard affordances.

The intricate, yet indispensable, nature of teaching and learning necessitates effective pedagogical strategies to cultivate learners' acquisition of knowledge and facilitate the educational system's advancement (Kapur, 2020). Integrating technology into pedagogical practices emerges as a promising avenue for enriching the quality of technology-mediated teaching and learning experiences. However, this approach hinges on teachers possessing a robust blend of technical proficiency, pedagogical expertise, and subject-matter knowledge for seamless integration within the classroom setting (Bolaji & Adeoye, 2022). This study will explore the pedagogical applications of diverse smartboard affordances in the teaching of photosynthesis.

Drawing upon Kapur (2020), pedagogy can be understood as the application of methodological frameworks and instructional strategies to facilitate learning. Furthermore, Bolaji and Adeoye (2022) emphasize the teacher's confidence in employing these strategies to achieve specific learning outcomes. While pedagogical practices establish the foundation for learning, ICT offers tools to enrich and personalize these practices. Nonetheless, the efficient integration of ICT like smartboard affordances into classrooms hinges on teachers' effective integration of these affordances within their existing teaching methods (Ifinedo et al., 2020).

According to Al-Kahlan and Khasawneh (2023), smartboard affordances promote clear learning objectives, emphasizing key concepts, and structuring information for optimal comprehension. Smartboard affordances facilitate enhanced pedagogical approaches in classrooms as they enable teachers to maintain mobility within the learning environment while simultaneously interacting with the smartboard using a smart slate (Qader, 2021). Smartboard affordances also allow for synchronous interaction by multiple users, including teachers and learners, who can collaboratively write and annotate on the smartboard surface thus improving learners' understanding (Samsonova, 2020).

This interactive technology fosters a highly engaging learning environment, empowering teachers to manage and engage the entire class as well as smaller learner groups throughout the instructional process (Qader, 2021). In this study, therefore, an exploration will be undertaken to identify and evaluate pedagogical methods that can be optimally utilized in conjunction with smartboard affordances to facilitate a deeper understanding of photosynthesis. Teachers can use the following smartboard affordances (as depicted on table 1) in the classroom as explained by Abdullah et al. (2020) and Bakare et al. (2021). This table describes smartboard affordances, such as touch sensitivity, annotation, and internet connectivity, that teachers can use to teach photosynthesis to Grade 11 learners. Furthermore, it organizes and clearly defines specific smartboard affordances and provides practical examples of how these can be applied in a teaching context. In this case, the table breaks down how a teacher could use affordances like touch sensitivity, the annotation tool, and internet connectivity to create an interactive and engaging lesson on photosynthesis for their learners.

Table 1: A summary of the smartboard affordances that can be used by teachers.

Smartboard affordance	**Description of a smartboard affordance and how it can be used**
Writing and Highlighting on the smartboard	This affordance can be used by learners and teachers to directly annotate their desktop with digital ink. They can be able to switch between various colours and utilize a highlighter to emphasize key sections of text or images. The pen tool can used for visual clarity since it offers customization options for size, colour. A digital eraser can also be used for quick removal of annotations (Abdullah et al.,2020).
Touch sensitivity	Teachers can use this affordance to write, draw, annotated, highlight, play, pause video, and safe work (Abdullah et al.,2020).

Timer	The teachers can use to manage the duration of activities and segments within a lesson. The timer can be set with audible alerts to signal the end of a designated time (Abdullah et al.,2020).
Animation video	The animation video can be used by teachers to create a dynamic visual effect (Abdullah et al.,2020).
Saving work	The teachers can save any work that was done on the smartboard to the smartboard and a USB. This presents the opportunity to share and reuse materials (Abdullah et al.,2020).
Internet connectivity	Teachers can use this affordance to conduct real-time internet searches for information, resources, and educational content (Bakare et al. ,2021).
Record affordance	The teachers can record and save the work for future reference (Bakare et al. ,2021).
smartboard software, such as Flipbook, Sphere 2 and IQ Interactive Education Platform.	Can be used to facilitate the learners learning activities by developing and delivering engaging visual presentations (Bakare et al. ,2021).
Digital Textbooks and Activity Books (Flipbook)	Teachers can use this affordance to access to the entire curriculum in a digital format. They can also use it to replace or supplement traditional physical textbooks (Bakare et al. ,2021).
Digital Document Presentation	Teachers can display and annotate class notes, word documents, and other digital files (Bakare et al. ,2021).
Interactive Learning Activities	Teachers can engage learners in interactive exercises, games, and simulations to reinforce learning (Bakare et al. ,2021).
Visual Data Presentation	Teachers can display and manipulate charts, figures, and other visual data to support data analysis and interpretation (Bakare et al. ,2021).

2.5 Teaching practices in integrating smartboard affordances with pedagogy.

Research emphasizes the necessity of smartboard affordances into teaching frameworks. Belay (2020) highlights this by underlining ICT's potential to optimize learner comprehension, knowledge retention, retrieval, and real-world application. Furthermore, studies by Alonso-García et al. (2019) demonstrate how ICT integration fosters a more engaging and relevant learning experience. The concept of "good practice" in ICT-based pedagogy revolves around methodologies that leverage technology to achieve positive learning outcomes. These methodologies, as outlined by Alonso-García et al. (2019), should be replicable across diverse teaching contexts.

"Best practices," however, represent particularly successful instructional approaches within specific learning environments. Ultimately, teaching requires catering to various learning styles (Munna & Kalam, 2021). In other words, pedagogical approaches emphasize a shift in focus from simply delivering content towards fostering meaningful learner learning outcomes. This principle, as articulated by Sarma (2024) underscores the importance of prioritizing learner understanding and engagement over content coverage. This shift necessitates a focus on instructional strategies that cultivate deep understanding, critical thinking skills, and the ability to apply knowledge to real-world scenarios.

Smartboard affordances provides teachers with a powerful and versatile teaching tool. These smartboard affordances go beyond simply displaying presentations. Teachers can leverage the smartboard affordances to create engaging lessons using familiar software like PowerPoint, while also integrating web browsing and virtual keyboard exercises (Al-Kahlan & Khasawneh, 2023). This not only enhances the learning experience but also introduces learners to foundational computer skills. Smartboards possess the potential to accommodate a multifaceted approach to learning, aligning with the auditory, visual, and kinesthetic (tactile) learning styles framework (Qader, 2021).

Teachers can utilise smartboard affordances to provide various teaching strategies and learning resources, accommodating diverse learning styles among learners. As noted by Hendawi and Nosair (2020), the smartboard's affordances to present visual content, such as images and videos, can be particularly advantageous for individuals who learn through visual methods. While individuals frequently prefer a specific learning modality, smartboards provide a versatile platform to address diverse preferences. They support auditory learners through group discussions, visual learners with rich multimedia content, and tactile learners by enabling direct interaction with the technology (Qader, 2021).

As mentioned before, smartboards are interactive whiteboards that combine the physicality of a traditional whiteboard with digital technology, it combines a projector, computer, and touch functionality (Issa, 2020). Teachers and learners can manipulate digital content directly on the board, accessing the internet and various applications. As a multimedia tool, they can display and manipulate various media formats such as text, images, and videos. Therefore, teachers can use smartboard affordances to offer a versatile learning environment, accommodating diverse teaching styles and catering to different learning needs (Rinekso & Lesagia, 2020). The smartboard affordances, including file browsing, document annotation, handwriting recognition, and image manipulation, enhance learner engagement and facilitate effective knowledge transfer (Rinekso & Lesagia, 2020).

2.6 Integrating smartboard affordances with pedagogy to teach photosynthesis and other topics in grade 11.

This study explores the integration of smartboard affordances, within the pedagogical framework employed by teachers when teaching grade 11 learners about photosynthesis.

2.6.1 What is photosynthesis?

Photosynthesis is the process where plants use sunlight as energy to convert water and carbon dioxide into sugar. Oxygen is produced as a byproduct of this chemical reaction (Bizimana et al., 2022). The oxygen released during photosynthesis replaces the oxygen required by living organisms through respiration (Lim & Poo, 2021). Photosynthesis begins with the light reaction, which occurs within the thylakoid membranes of chloroplasts. This process involves the splitting of water molecules, releasing hydrogen ions, electrons, and oxygen gas (Hossain et al.,2022). The energy from sunlight is used to create a concentration gradient of hydrogen ions across the thylakoid membrane. As these ions flow back across the membrane, energy is released and used to produce ATP, a molecule that stores energy for the plant (Hossain et al.,2022). This is then followed by the Calvin cycle, which occurs within the chloroplast stroma, uses a continuous set of processes to convert carbon dioxide into organic molecules (Baslam et al.,2020).

2.6.2 Why photosynthesis?

Photosynthesis, a crucial biochemical process, transforms carbon dioxide into glucose (Woldeamanuel et al., 2020). It constitutes the most fundamental metabolic activity on Earth, directly or indirectly sustaining most living organisms. Understanding photosynthesis is fundamental to grasping a broader range of environmental issues. Saka (2019) emphasizes that a solid foundation in photosynthesis allows individuals to better comprehend the state of the atmosphere, the role of greenhouse gases, climate change, carbon footprints, and the importance of forest conservation. Ultimately, this knowledge empowers citizens to make informed decisions for a sustainable environment (Saka, 2019).

However, as previously mentioned, the specific focus on photosynthesis in this study stems from the numerous challenges it presents for both learners and teachers (Fermani & Georgiou, 2023). Although photosynthesis represents a fundamental concept introduced in primary schools and revisited throughout higher education (Li, 2022), its inherent complexity necessitates the unpacking of various underlying conceptual elements. In simpler terms, while learners encounter photosynthesis at a basic level early on, a deeper understanding necessitates delving into the intricacies of the process throughout their academic journey (Li, 2022).

Encompassing ecological, physiological, biochemical, and energetic concepts, this topic is notoriously difficult for learners to grasp. While they often memorize the basic definition and equation, the underlying concepts involving anatomy, biochemistry, ecology, energy transformations, and physiology are interconnected and intricate (Ahmed & Lawal ,2020). To grasp photosynthesis fully, learners require a solid foundation in chemistry, including chemical reactions, organic and inorganic molecules. Consequently, teachers must employ effective teaching strategies to simplify these complex ideas and enhance learner understanding of photosynthesis and the can use the smartboard to do so.

2.6.3 What literature says about the teaching and learning of photosynthesis

Photosynthesis is a fundamental scientific concept taught across various educational levels (Pamungkas et al., 2019). However, understanding the process by which plants convert sunlight into energy, known as photosynthesis, is a complex challenge for learners at all levels, from primary to secondary school. Teachers and those preparing to teach also find this concept difficult to explain (Vančugovienė et al., 2023). Current photosynthesis education is unsuccessful in increasing scientific literacy. Learners fail to understand the relevance and underlying mechanisms of photosynthesis owing to the abstract nature of the information being give (Eriksson et al.,2024).

2.6.3.1 Difficulties encountered during the teaching and learning of photosynthesis

As already mentioned, photosynthesis is a complex biological process that poses significant challenges for life sciences learners due to its abstract nature and complicated chemical composition (Aristyasari & Yuliani, 2021). Several factors contribute to learners' difficulty understanding this biological concept in addition to its abstract nature. The several factors include insufficient resources, such as textbooks, overloaded curriculum, and poor learning settings, particularly in rural regions, hinders effective learning (Bizimana et al.,2022). A lack of instructional resources, along with underqualified and demoralised teachers, leads to the problem. Notably, the use of inadequate teaching approaches is a major source of learners' difficulty learning biology knowledge (Bizimana et al.,2022).

The article by Manullang et al. (2021) highlights that teachers often face difficulties in adapting their teaching methods to cater to the specific needs of their learners. This is partially attributed to the instructional methodologies and resources commonly employed in general education classrooms. As a result, learners may encounter challenges in their learning experiences. Misconceptions are also part of the reason that makes the teaching and learning of photosynthesis a challenge to both the learners and teachers. Almualimah et al. (2024) argue that learners learn photosynthesis through rote memorization without conceptual comprehension. This memorization method hinders the application of knowledge to problem-solving, particularly in life sciences where understanding underlying principles is paramount (Almualimah et al., 2024).

2.6.3.2 Photosynthesis misconceptions

Learners in a classroom have diverse thinking styles, leading to different understandings of information presented by the teacher (Pamungkas et al., 2019). This individual interpretation of information can result in varied concepts and misconception, especially when learning complex topics like photosynthesis (Pamungkas et al., 2019). Misconceptions, defined as scientifically inaccurate beliefs often instilled during early education experiences or through the transmission of misconceptions held by teachers themselves tend to become ingrained over time (Karakaya et al., 2021).

Misconceptions about photosynthesis hinder understanding but addressing them empowers learners to build and share scientific knowledge by actively connecting new information to their existing frameworks (Woldeamanuel et al., 2020). Furthermore, Jayanti (2019) suggests that a failure to address pre-existing knowledge and integrate it with the introduction of new information in the classroom setting can lead to the development of misconceptions. This impediment in the assimilation process hinders the establishment of accurate understanding. A common misconception among learners is the belief that plants absorb nutrients directly from their environment as food, rather than synthesizing their own through photosynthesis (Woldeamanuel et al., 2020).

Learners commonly misunderstand the interconnectedness of photosynthesis and respiration in plants, believing photosynthesis directly provides energy without the intermediary step of respiration (Lim & Poo, 2021). Many learners mistakenly believe that plants obtain their nourishment solely through their roots (Vančugovienė et al.,2023). Additionally, learners hold inaccurate views about the reactants and products involved in these processes, such as the role of water and the production of glucose during photosynthesis (Lim & Poo, 2021).

2.7 Integration of smartboard affordances with pedagogy when teaching photosynthesis

In this study, the researcher argued that teachers can use smartboard affordances in conjunction with pedagogy to help learners comprehend photosynthesis. For example, teachers can use affordances like animations and simulations to display and represent the process of photosynthesis in a degree of visualization that cannot be achieved by traditional visualization methods (Bernátová et al., 2020). For instance, the teacher can show the class a simulation video that breaks down the process into a way that can be simply understood by the learners or conduct experimental simulations with them or display a diagram that illustrates causality of photosynthesis.

Ruzaman's (2020) study employed a two-dimensional (2D) simulation within the engagement phase to elucidate the essential requirements for plant food production, otherwise known as photosynthesis. In addition to providing a deeper understanding of biological phenomena, simulations can also be used to create virtual replicas of biological structures and processes (Mkhanyiswa, 2022). This educational tool offers a valuable alternative to traditional wet lab experiments, especially for studying complex or ethically problematic dissections, ultimately enriching the learning experience (Mkhanyiswa, 2022).

This integration of smartboard affordances served to demonstrate the key factors necessary for this vital biological process. The teachers can apply affordances like interactive components called interactive computer graphics (hypertext, drag and drop, etc.) found in the smartboard to do all that is mentioned above (Bernátová et al., 2020). Furthermore, in an analysis of effective smart board usage, Petruţa (2016) highlights the pedagogical value of interactive elements. Specifically, when teaching about the skeletal system, utilizing a 3D model allows teachers to manipulate and explain individual components. This approach, as Bajracharya (2021) notes, aligns with the augmentation level of the SAMR model (which will be discussed later in this chapter), as the rotating image enhances the learning experience beyond static presentations.

2.8 The gap in integrating smartboard affordances with pedagogy.

There are existing challenges that affect the smartboard affordances integration with pedagogy to support effective teaching and learning. However, this study will not be focusing on learning and learner academic performance it will be mostly looking at how teachers integrate smartboard affordances with pedagogy to teach photosynthesis in the grade 11 classroom. Regarding this, the challenges that teachers face include a lack of smartboard knowledge and experience. Smartboard affordances can only be used if teachers are properly trained. Adequate teaching time is critical for teachers to manage classes and minimise interruptions caused by technological issues (Issa, 2020).

Amongst other challenges, two major challenges impede the efficient usage of smartboard affordances in schools. First, many teachers lack the expertise required to utilise smartboard affordances, resulting in rare or poor usage of this technology. Second, when smartboard affordances are employed, the emphasis frequently changes away from teaching techniques (pedagogy) and onto the technology itself, reducing the teacher's role in the learning process (Mokoena et al.,2022). Ramorola (2014) argues that teachers may lack knowledge in two ways: a lack of skills and expertise in using technology and a lack of pedagogical knowledge in using technology appropriately. The focus of the study is to understand how teachers use smartboard affordances to enhance their teaching of photosynthesis.

The findings from the research conducted by Mokoena et al. (2022) revealed that teachers used smartboards as a projector. The study also showed that most teachers received training on how to use the smartboard affordances, but the training was inadequate. This was not satisfactory according to the participants, as most training sessions were carried out by education officials who lacked pedagogical knowledge. Integrating smartboard affordances in teaching also faces challenges such as high costs, technical difficulties, maintenance needs, and potential health issues like eye strain, alongside operational problems like speaker volume and screen reflection (Uqba et al., 2024). Furthermore, smartboard affordances are hindered by practical issues including lost styluses, connectivity problems, slow performance, virus vulnerabilities, and software incompatibility (Uqba et al., 2024).

Dlamini (2022) underscores the importance of achieving a balance between ensuring equitable access to ICT infrastructure and fostering educator competency through well-designed professional development programs. This balanced approach acknowledges that technology is but a tool, and its effectiveness hinges on both its accessibility and the capacity of educators to leverage it for pedagogical purposes (Dlamini, 2022). Professional teacher development programs equip educators with the knowledge and skills necessary to thrive in a digital society, focusing on improving their understanding and proficiency in ICTs to integrate technology into their teaching and learning practices (Kgosi et al., 2023). Furthermore, Tsai (2019) highlights the challenges of integrating smartboards in education, emphasizing the need for appropriate resources, teacher training, and pedagogical strategies to overcome potential drawbacks and leverage its potential benefits. Therefore, although smartboard has the potential to provide significant advantages, achieving these benefits requires focused efforts to address underlying challenges.

2.9 Findings from other researchers on the use of smartboard affordances in the classroom.

Hussein et al. (2022) demonstrated that Smartboard affordances not only saved time and effort for teachers but also facilitated improved learning outcomes for learners. However, Suliman and Ahmed (2020) highlighted the lack of adequate training for teachers in utilizing Smartboard affordances within the classroom setting. This underscores the crucial need to advocate for the Department of Education and teachers to recognize the importance of not only providing access to Smartboard affordances but also investing in professional development programs to ensure its effective utilization.

Equivalent results were found on Akar's (2020) study, employing a mixed-methods approach (quantitative and qualitative), investigated the impact of smartboards on academic achievement. The findings revealed a positive, significant, and large effect size for smartboard use on academic outcomes, suggesting that integrating smartboard affordances in classrooms, as compared to traditional tools, can lead to improved learner performance (Akar, 2020). Added to that, Mtshali (2021) investigated the use of smartboard affordances as scaffolding tools in Grade 12 Life Sciences, finding them effective for introducing complex topics with multimedia elements. However, the study revealed underutilization of smartboards affordances, highlighting a need for maximizing their pedagogical potential.

Tsayang et al. (2020) found that smartboard facilitate learner participation and active learning through diverse affordances, highlighting the crucial role of engagement in effective teaching. Furthermore, enabling learners to interact with the content through various activities, smartboard affordances can enhance their understanding. Stated differently, the study conducted by Mun et al. (2019) suggests that incorporating smartboard affordances with active learning environments can enhance learner engagement and cater to diverse learning styles by facilitating direct interaction with the content and manipulating information on a large display.

2.10 Conceptual frameworks for the study

2.10.1 The Refined Consensus Model of PCK

Education changed in the 1980s because of a renewed emphasis on teaching methods and subject-matter competence. In support of a complete approach to teacher preparation, Lee Shulman emphasised the value of both pedagogical and subject knowledge (Telesphore et al., 2023). To close the gap between these two fields, he developed the idea of pedagogical content knowledge (PCK), which holds that presenting knowledge to learners in a way they can grasp needs a profound understanding of the topic. Shulman's more complete theory of teacher knowledge included knowledge of the curriculum and the educational setting. This pedagogical content knowledge can be further defined as a teacher's proficiency in helping learners understand topics that are challenging (Salgado, 2024).

In other words, teachers can break down topics into comprehensible components by understanding their learners' prior knowledge, challenges with learning, and how they perceive information. With this specific knowledge, teachers may choose and implement teaching methods that avoid misconceptions and promote academic success for learners (Salgado, 2024). Essentially, the foundation of good teaching is pedagogical content knowledge, which elevates teaching from a simple duty to a profession. The Refined Consensus Model of Pedagogical Content Knowledge (PCK) provides a sophisticated look at the varied nature of PCK. While the initial concept of PCK emphasised the confluence of content and pedagogy, the modified model incorporates five constructs namely the collective PCK, personal PCK, and enacted PCK, learning context and the professional knowledge bases (Roy & Bairagya, 2019).

1. **Collective PCK (cPCK)**

Collective PCK is a dynamic construct that includes learner cognition, pedagogical techniques, and a teacher's in-depth subject-matter knowledge. From general discipline knowledge to conceptual applications, it advances (Kılıç, 2024). With this specific knowledge, educators may help learners overcome misconceptions, create engaging lessons, and support conceptual growth in a certain topic like photosynthesis (Behling et al.,2022). For instance, in this study, the researcher will work with three teachers respectively to teach the grade 11 learners photosynthesis using a smartboard. Therefore, the teachers will need to understand photosynthesis, including light-dependent and independent reactions, factors affecting the rate of photosynthesis, and its role in the ecosystem. During their planning as a collective, the teachers will need to select effective teaching methods to convey complex concept of photosynthesis, such as playing a short video clip explaining photosynthesis in simple terms. In addition to this, the teachers should have awareness of how learners learn and potential misconceptions they might bring in the classroom either from their everyday lives or previous grade, such as thinking that plants only produce oxygen during the day.

2. Personal PCK (pPCK)

Personal PCK represents a teacher's continually evolving knowledge and skills in their subject area. It is shaped by their personal teaching and learning experiences, as well as insights gained from colleagues, researchers, and experts. This knowledge pool is enriched through professional development, academic resources, and the diverse perspectives of learners over time (Roy & Bairagya, 2019). For instance, a teacher's pPCK in life sciences would be evident when teaching photosynthesis using a smartboard. They might draw on their own understanding of the process, combined with knowledge from discussions with colleagues. However, despite planning lessons with their colleagues, teachers can implement their own pPCK by diverting from the collective PCK to tailor the lesson to their learners' needs, using interactive elements on the smartboard, such as animations and simulations, to make complex concepts understandable. They might incorporate real-world examples, such as the role of photosynthesis in the ecosystem using colourful diagrams to grasp the learner's attention, to connect the topic to their lives. This approach, informed by their pPCK, would create an engaging and effective learning experience.

3. Enacted PCK (ePCK)

Enacted PCK is essentially a teacher's practical knowledge in action. It showcases how teachers apply their theoretical understanding in real classroom settings. This knowledge is crucial for making split-second decisions based on unexpected events during lessons, and it influences how teachers interpret and respond to learners' needs and behaviours in the moment (Irmer et al.,2023). For instance, during a photosynthesis lesson using a smartboard, a teacher might notice learners struggling with the concept of chlorophyll. Using their ePCK, they could quickly decide to show a visual animation of chlorophyll's role or perhaps ask a probing question to stimulate discussion using a picture that displays green trees, all while considering the class's energy level and time constraints.

4. Learning context

The setting or the environment like a classroom in which learning takes place or where educational processes take place is known as context (Alshumaimeri, 2023). Several characteristics need to be considered when referring to 'context' such as culture, gender, age, the size of the classroom, learning and teaching resources available, and location (Carlson & Daehler, 2019). An example of an educational context would where there are limited resources, overcrowding which can make it a challenge for teachers to create a learning environment where there is learner engagement as opposed to a school where there are resource and about 25 learners in each class where their teacher is able to utilize the available resources like smartboards to create a learning environment that is very interactive.

5. Professional Knowledge Bases

1. Content knowledge (CK)

Content knowledge is described by Redmond and Lock (2019) as the knowledge that teachers need to have in relation to the content they will teach the learners. This knowledge includes theories, concepts, principles, facts and ideas of the content (Nautiyal & Dabral, 2023). An example of content knowledge in the life sciences classroom would include a teacher who comprehends topics like photosynthesis, excretion, ecology, evolution and more.

2. Pedagogical knowledge (PK)

Pedagogical knowledge involves planning and evaluation of teaching, classroom management to assist the teachers to manage and guide the learning processes in the classroom (Paidican & Arredondo, 2022; Susanto et al., 2019). This is the knowledge that relates to how teachers teach a subject, including their awareness of potential learner misconceptions (Filgona et al., 2020). For instance, in the photosynthesis classroom, the teachers will have to do a proper planning, be aware of the learner's misconceptions such as plants do not respire, come up with strategies to address these misconceptions during the planning process, know which teaching strategies to use and representations to use like problem solving, group work, real world connections, simulations, models and more.

3. **Knowledge of the learners (KL)**

Knowledge of the learners is related to understanding the learner's prior knowledge from either the previous grades or from their everyday lives in relation to a particular topic like cellular respiration, genetics, plant tissues and more. This also includes teachers understanding of the learner's possible misconceptions and the teacher's competence in addressing those misconceptions (Botha et al., 2023). Furthermore, understanding learners necessitates an understanding of their individual characteristics, including their diverse learning styles, abilities, and personal academic aspirations (Sarkar et al., 2024).

4. **Curricular knowledge (CUR)**

Curriculum knowledge encompasses a broad understanding of educational goals, learning objectives for each lesson, and program structures. It also includes familiarity with specific teaching materials like models, handouts, and charts, standards, and resources that are relevant and effective for learner learning (Appova & Taylor, 2020). For instance, teachers will need to understand the objectives of the Curriculum and Assessment Policy Statements (CAPS), have knowledge about the Annual Teaching Plans (ATP) which outlines key concepts and skills to be taught to the learners, along with the appropriate timing for teaching them in each grade. In simpler terms to understand curricula means being familiar with the entire educational plan, including what learners are expected to learn, how the subjects are organized, and the materials used to teach each topic (Sarkar et al., 2024).

5. **Assessment knowledge (AK)**

Assessment knowledge involves teachers understanding of how to evaluate the learners. In other words, teachers must give learners an assessment that aim to achieve specific outcomes (Sarkar et al., 2024). For instance, in a human reproduction lesson, the teacher can give learners a crossword puzzle activity with an aim of teaching learners how to write the correct biological terms spelling or display an animation video to demonstrate to the learners how the ovum moves from the fallopian tubes to the endometrium.

The professional knowledge bases of the refined consensus model of PCK overlap with one another to create effective instruction in the classroom. For instance, in the photosynthesis classroom, the teacher's curriculum knowledge will guide them to select relevant photosynthesis concepts that aligns with the learning objectives. Furthermore, the knowledge of the learners will assist the teachers to identify the learner's misconceptions about photosynthesis and provide a guidance for the engaging teaching strategies to use. The teaching strategies that teachers can choose to use in the classroom can also be influenced by learning context. For instance, you cannot include playing a video for the learners while you do not have the resources to do so. This can also assist teachers to design formative and summative assessments that will allow them to know how much learners understand. For instance, the teacher can use a smartboard to create a quiz that can provide learners with immediate feedback.

Essentially, the PCK components provide a detailed breakdown of the broader PCK constructs within the refined consensus model. Through understanding the distinction within each component, teachers can develop a more refined approach to teaching, adjusting their instruction to meet the specific needs of their learners and contexts. Therefore, Refined Consensus Model of PCK was used in this study to explore the use of smartboards in teaching photosynthesis to Grade 11 learners by focussing on the interaction of teachers' collective, personal, and enacted PCK connected to photosynthesis and smartboard affordances. Figure 1 below shows the refined consensus models as described above. This figure displays a relationship between different types of pedagogical content knowledge and other knowledge bases essential for teaching. This diagram is important because it shows how a teacher's personal knowledge, and the collective knowledge, is constantly developed and refined through the cyclical process of planning, teaching, and reflecting.

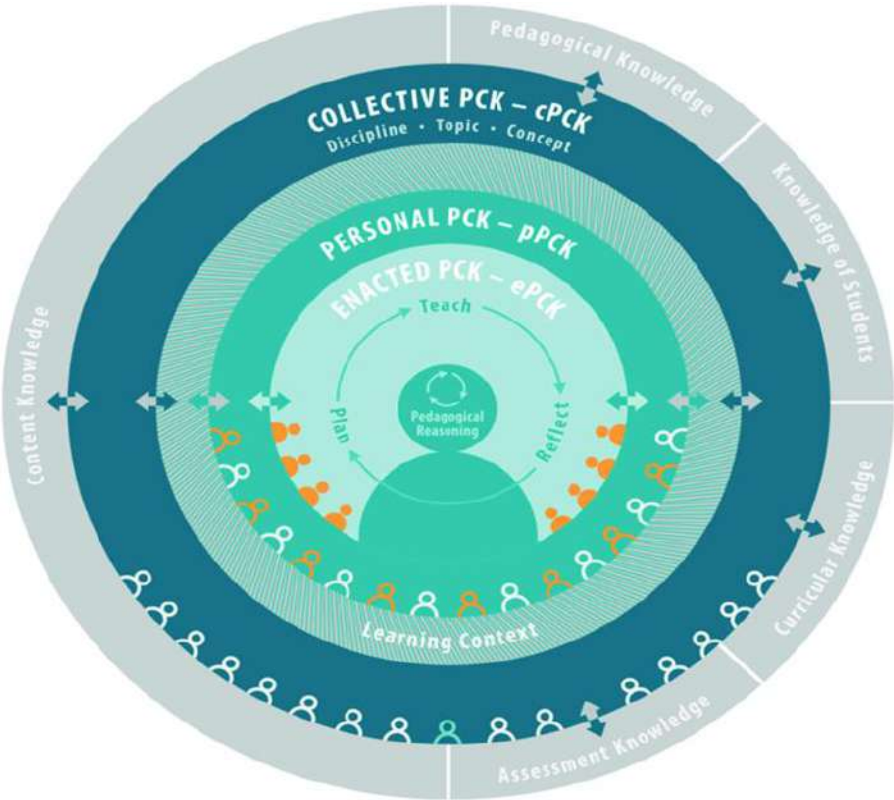

Figure 1: A summary of refined consensus model of PCK

2.10.2 The Substitution, Augmentation, Modification, and Redefinition (SAMR) Model

Puentedura's SAMR framework, encompassing Substitution (S), Augmentation (A), Modification (M), and Redefinition (R), it is a model that offers a nuanced lens for analysing technology integration in the classroom (Gillespie, 2022). At its core, SAMR guides educators in harnessing technology's potential to enrich learning experiences (Bajracharya, 2021). In its most basic form, the substitution level can be characterized by a direct exchange of conventional tools with their technological equivalents, with the fundamental nature of the activity remaining unaltered. This implies that, at this stage, technology functions as a simple replacement, offering no significant alteration to the task's inherent structure or function (Daudi & Nzilano, 2019). In this study, during the lesson observations, the researcher will be looking at instances such as teacher opening a textbook from the smart board instead of opening a physical textbook.

Augmentation, however, signifies a shift towards utilizing technology to augment existing activities, thereby introducing functional change, and enhancing learning outcomes (Wahyuni et al., 2020). Augmentation can involve using the board for simulations, interactive quizzes, or learner presentations that incorporate multimedia elements (Rosales, 2021). During the lesson observations the researcher will be looking for instances where the teacher plays a simulation video that shows the events that occur during photosynthesis to make it easy for learners to grasp the content knowledge. Modification is the third component of SAMR model that marks a more significant transformation, where technology facilitates the redesign of tasks, leading to substantial improvements in instructional delivery (Wahyuni et al., 2020).

Furthermore, learning objectives at the modification tier necessitate the fulfilment of specific goals established for a given lesson. Technological tools can facilitate the adaptation of teaching methodologies while preserving the core elements of the curriculum (syllabus). This allows for the modification of the pedagogical approach, ultimately enabling learners to achieve previously unattainable learning outcomes (Radhi & Sabri, 2021). For example, during lesson observations the researcher will be looking at instances where the teacher asks learners to work as the class whereby one learner draws a diagram of a chloroplast on the smartboard and the rest of the learners put in the labels using different colours. This is to see if whether the teacher can use smartboard to foster learner engagement during the lesson. This overlaps with the sociocultural theory since there learners will be interacting with each other, and language will be used as a mediation tool since they will have to talk to each other and complete this activity as a group.

Contemporary education is witnessing a paradigm shift in its approach to technology integration, transcending mere utilization and venturing into the realm of redefinition. This burgeoning stage, as articulated by Wahyuni et al. (2020), empowers educators to harness the transformative potential of technology in crafting entirely novel learning experiences and functionalities, fundamentally reshaping the educational landscape. Teachers ascend from simply incorporating technology into existing frameworks to reimagining instructional practices altogether by embracing redefinition, (Radhi & Sabri, 2021). Redefinition uses technology to create entirely new learning experiences (Rosales, 2021).

To leverage the affordances of smartboards, teachers should strive to move beyond mere substitution and modification. This necessitates the integration of technology-driven pedagogical approaches, fostering enhanced learner engagement and propelling learners towards a deeper understanding of the subject matter. For example, during lesson observations, the researcher will be looking at instances where learners are asked to make power point presentations where they will have to displace their presentations and explain photosynthesis sub-concepts like dark phase, light phase, factors that affect the rate of photosynthesis. Another example of redefinition might involve collaborative diagrammatic flow diagram on the smartboard that summarise a process of photosynthesis for instant (Rosales, 2021).

This framework transcends mere evaluation of technology use and explore in depth the pedagogical integration of ICT (Alivi, 2019). The framework's core objective, as outlined by Bajracharya (2021), is to guide educators in incorporating technology not as a simple replacement, but as a tool that unlocks new learning possibilities. While substitution simply replaces traditional tools with digital ones, the latter three levels leverage technology to transform learning activities and introduce new functionalities, holding greater potential for enhancing teaching and learning (Bajracharya, 2021). This study utilized the SAMR model to design technology-integrated lessons and identify effective pedagogical approaches for grade 11 photosynthesis instruction. Figure 2 below shows a summary of SAMR Model which categorizes the use of technology in education into four levels: Substitution, Augmentation, Modification, and Redefinition. It is important because it provides a framework for teachers to evaluate how they are integrating technology, moving from simple substitution (Enhancement) to creating entirely new learning experiences (Transformation).

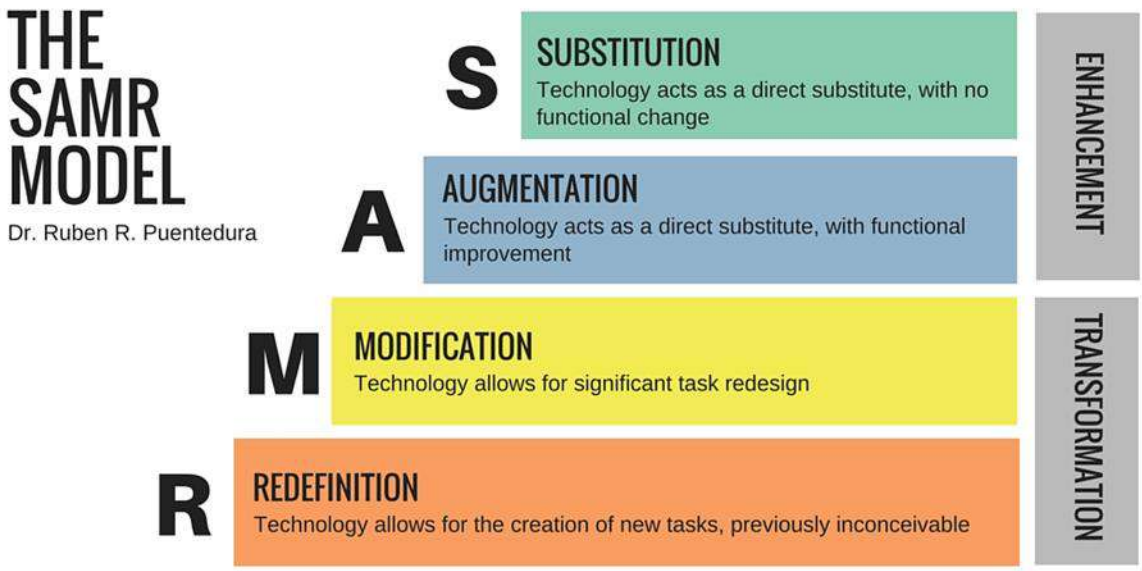

Figure 2: A summary of SAMR Model.

2.11 Conclusion

The literature highlights smartboards as powerful tools for enhancing education through interactive and engaging learning experiences, particularly for complex subjects like photosynthesis. Smartboards affordances, cater to diverse learning styles and improve learner engagement and comprehension. However, effective integration of smartboard affordances requires teachers to possess both technical skills and pedagogical expertise. A key challenge is that many teachers lack adequate training, often using smartboards merely as projectors. This gap between technology access and pedagogical integration necessitates focused professional development to equip teachers with the skills to strategically utilize smartboard affordances, ultimately transforming classrooms into environments where learners actively construct knowledge. The research aims to explore how teachers integrate smartboard affordances with pedagogical approaches in teaching photosynthesis to Grade 11, identifying best practices for maximizing the educational potential of this technology.

Chapter 3

Research Design and Methodology

3.0 Introduction

Following a review of the relevant literature in the previous chapter, this section describes the methodological framework and research design underpinning the present study. Specifically, it elaborates on the chosen sample selection methodology, ethical considerations, and the research instrumentation that will be employed for data collection.

3.1 Research method

This study adopts a qualitative research design, which is defined by Adeoye-Olatunde and Olenik (2021), as a diverse methodology suitable for examining phenomena within natural settings. The chosen design prioritizes gathering rich narrative data from participants, either individually or collectively, aiming to achieve a nuanced understanding of the research question. In this study, data was gathered both individually and collectively. Individually it was collected from teachers from each school when they were interviewed prior the first lesson observation and after both lesson observations. Data was collected collectively from both teachers and learners simultaneously. Observations were made to determine how the learners respond to how they are taught and how do the teachers use smartboard to teach their learners and how frequently are the components of both the refined consensus model of PCK and the SAMR model are used. While a variety of qualitative methods exist, this study's primary data collection relied on established techniques, such as semi-structured interviews and observations, which will be explained in section 3.5 (Adeoye-Olatunde & Olenik, 2021).

3.2 Research paradigm

Interpretivism refers to studies of how people shape and understand reality through social interactions and cultural contexts (Pervin & Mokhtar, 2022). Research seeking a rich understanding of social realities views reality as a social construct, not an objective truth, and uses diverse methods to consider context, culture, and individual meanings (Alharahsheh & Pius, 2020; Pervin & Mokhtar, 2022). This investigation adopts an interpretivist paradigm to elicit the subjective experiences of three grade 11 life sciences teachers and their learners regarding the integration of a smartboard to facilitate photosynthesis instruction for grade 11 learners. The qualitative inquiry will pay more details on the teacher’s unique perspective and lived experiences, aiming to capture the nuanced and subjective understanding of this integration process. Therefore, during data collection, the researcher depended on the teachers teaching experience and their pedagogical methodologies.

3.3 Research design

The study investigated how teachers used smartboard affordances to teach photosynthesis in Grade 11, employing a multiple case study design across three Gauteng secondary schools. This choice, as Bressanelli et al. (2019) described, involved conducting case research in multiple settings. The study aimed to examine these instances to determine both unique and shared characteristics. This approach, as Gustafsson (2017) indicated, allowed for stronger and more dependable results through individual and comparative case analysis. Consequently, the researcher identified recurring patterns and significant differences, which contributed to a more nuanced understanding of the research topic. Ultimately, the study developed stronger theoretical foundations by grounding its findings in diverse real-world examples, thereby providing an answer to the research questions (Gustafsson, 2017). The case studies are described in the next section.

3.4 Participants: Participating schools, teachers and the researcher

Adeoye-Olatunde & Olenik (2021) emphasise that selecting participants in qualitative research requires careful consideration to ensure the credibility of the findings, necessitating a refined approach that balances subject matter expertise with diverse perspectives to achieve rich data. Therefore, this study adopted purposeful sampling, a non-probability method aligned with qualitative research's focus on in-depth understanding over generalizability (Adeoye-Olatunde & Olenik, 2021). Furthermore, this purposive sampling method ensured the selection of highly relevant participants who are all grade 11 life sciences teachers, thereby optimizing research efficiency and cost-effectiveness (Ndlovu, 2021). From each of the three participating schools, one teacher was selected based on a combination of factors: their strong pedagogical content knowledge regarding photosynthesis, the availability of smartboard technology in their classroom, and their show of confidence in using that technology through personal communication. The age of the teachers ranged from 25 to 29 years old. In addition to the three participating teachers and the researcher, the study included 119 Grade 11 Life Sciences learners from three different schools, with participant numbers of 37 at School 1, 39 at School 2, and 43 at School 3. The age of the learners ranged from 16 to 19 years old. The selection criteria for learners were enrolment in Grade 11 and Life Sciences.

3.4.1 Research Sites

This study employed a multiple case study design, selecting three secondary schools in Gauteng province to investigate the pedagogical integration of smartboard affordances in teaching photosynthesis. The selection aimed to capture diverse contexts, while ensuring participants possessed the necessary expertise.

3.4.1.1 School 1: Suburban Semi-Public School

Located at Johannesburg East district at a suburban area, this school operates as a semi-public institution, requiring learners to pay school fees. However, a provision for fee exemption exists for families facing financial constraints. The school receives funding from the Department of Education, supplemented by fundraising initiatives from the School Governing Body, staff, and external sponsors. This school was selected due to the availability of a smartboard and the teachers demonstrated familiarity with its use. The teacher at this site had over three years of Grade 11 Life Sciences teaching experience and was a digital native, aged between 25 and 28, holding a Bachelor of Education degree with a life sciences major. They also possessed experience teaching photosynthesis to Grade 8 learners. This site offered a context where resources and teacher proficiency were relatively high.

3.4.1.2 School 2: Township Government School

Located at Johannesburg East district at a township area, this school is a fully government-funded institution, with learners not required to pay school fees. Funding primarily comes from the Department of Education, supplemented by fundraising efforts. This school was chosen based on the availability of a smartboard and the teachers' familiarity with its utilization. Similarly to the first school, the teacher had over three years of Grade 11 Life Sciences teaching experience, was a digital native, and held a Bachelor of Education degree with a life sciences major. Their experience extended to teaching photosynthesis to Grade 8 learners. The township context provided a contrasting environment, potentially highlighting the impact of resource availability on smartboard integration.

3.4.1.3 School 3: Township Government School

Also located at Johannesburg East district at a township area, this school shares the same funding and fee structure as School 2. Its selection was based on the same criteria: smartboard availability and teacher familiarity. The teacher here also matched the profile of the other two sites, possessing over three years of Grade 11 Life Sciences teaching experience, being a digital native, and holding a Bachelor of Education degree with a life sciences major, and experience in teaching photosynthesis to grade 8. The inclusion of two township schools allowed for a comparison of contexts within similar resource constraints, potentially revealing nuanced differences in smartboard integration practices.

The table below compares three different South African schools by detailing their location, government status, socio-economic quantile, fees, and available resources like smartboards and internet. It is important because it highlights the significant disparities in resources and learning environments between schools in different communities, even when they are all government schools.

Table 2: A summary of participating schools and their context.

School name	**School 1**	**School 2**	**School 3**
Location	**Suburb** (residential area located on the outskirts of a city or large town. It typically features single-family homes, green spaces, and a quieter, less dense environment than the urban core (Terbeck, 2020).	**Township** (underdeveloped urban characterized by a lack of basic infrastructure and services and remain distinct from affluent urban and suburban areas)	**Township** (underdeveloped urban characterized by a lack of basic infrastructure and services and remain distinct from affluent urban and suburban areas)
Government school	Yes	Yes	Yes
Quantile- a term used to categorize public schools based on the socio-economic status of the communities they serve.	**Quantile 5-** located in more affluent communities, generally benefit from substantial resources, including higher funding allocations, well-maintained facilities	**Quantile 1 -**located in economically disadvantaged areas, often face significant resource constraints, including limited funding, infrastructure, and access to qualified educators.	**Quantile 1 -**located in economically disadvantaged areas, often face significant resource constraints, including limited funding, infrastructure, and access to qualified educators.
Fee paying school	Yes	No	No
Smartboard availability	Yes	Yes	Yes
Condition of the smartboard	**Good** (fully functional, with a responsive touch screen, clear display, and all software and connectivity features working properly).	**Fair** (has noticeable cosmetic wear, such as scratches or scuff marks, and minor functional issues that do not impede its primary purpose, such as occasional calibration or connectivity quirks)	**Good** (fully functional, with a responsive touch screen, clear display, and all software and connectivity features working properly)
Additional learning resources like charts	Yes, but not relevant to photosynthesis.	No	Yes, but not relevant to photosynthesis.

inside the classroom			
Electricity availability	Yes, however the school is affected by load shedding and load reduction.	Yes, however the school is affected by load shedding and load reduction.	Yes, however, due to overloading, illegal connections, vandalism and theft around the area the electricity goes off frequently.
Internet connectivity	Teachers need to bring their own Wi-Fi.	Teachers need to bring their own Wi-Fi.	The smartboard has internet connection.
Number of learners in the grade 11 class	39	33	41

Figure 3: School 1 classroom.

Figure 3 offers a visual representation of the classroom environment at School 1, which served as a data collection setting for the study. A smartboard is visible in the background of the top of this figure. This setup is significant as it visually contextualizes the primary focus of the research which is the integration of smartboard affordances with pedagogical practices. The general condition of the room, with chairs placed on top of the desks, shows that the image was taken during a non-instructional period. This allows for a clear view of the physical layout and resources available to the participating teacher and learners during the lessons observed.

Figure 4: School 2 classroom.

Figure 4 depict the classroom environment at School 2, which served as a data collection site for the study. The classroom is arranged in a traditional, forward-facing setup, with individual desks and chairs organized in rows. This configuration suggests a conventional instructional approach, which provides a relevant context for analysing how a teacher integrates smartboard within a standard classroom layout. Smartboard is visible on the right. The researcher's capture of this setting is crucial for contextualizing the observational data and understanding the resources available to the participating teacher when planning and delivering lessons on photosynthesis.

Figure 5: School 3 classroom.

The classroom in Figure 5 above was used for data collection at School 1. The classroom is well furnished, but it lacked charts relevant to any content. The figure documents the classroom environment at School 3, which served as the data collection site for a participating teacher. The room's setup consists of individual learner desks, many of which appear to be single-seater units, arranged in rows. The front of the classroom is equipped with a smartboard, similar to the setup at School 2. The smartboard's presence is a crucial element, as its availability and physical condition directly impact on the teacher's ability to leverage its affordances. The overall context of the classroom provides a rich setting for the researcher to observe how a teacher navigates the smartboard to deliver lessons on photosynthesis.

The table below provides demographic and professional information about three teachers: Jade, Samantha, and Zandaya as well as a researcher detailing their years of experience, qualifications, and the number of learners in their Grade 11 classes.

Table 3: A summary of participating teacher's biography.

Name of the teacher	Jade	Samantha	Zandaya	Researcher
Grades taught by the teachers in 2024	Grade 8, 10, 11, 12	Grade 8, 10, 11	Grade 8, 11, 12	Grade 10, 11, 12
Experience in years in teaching life sciences grade 11 *(as of 2024)*	5 years	4 years	5 years	4 years
Highest qualification *(as of 2024)*	Bachelor of Education Honours	Bachelor of Education	Bachelor of Education Honours	Bachelor of Education Honours
Age *(as of 2024)*	<30	<30	<30	<30
Number of learners in the grade 11 class	39	33	41	School 1- 39 School 2- 33 School 3- 41

3.5 Data collection method

In this study lesson planning, semi-structured interview questions, participant observation and video recordings were used as data collection methods. The first data collection method used was semi-structured interviews. This was the first step because it was necessary to gather initial insights from the participants before the practical aspects of the research, such as creating lesson plans and teaching the lessons, could begin. The interviews allowed the researcher to understand the participants' perspectives, experiences, and prior knowledge. This foundational information was then used to inform and guide the subsequent steps, specifically the development of the collaborative lesson plan. Without this initial data from the interviews, the researcher would not have the necessary context to design the lessons and proceed with the rest of the data collection process. The audio recordings served as a detailed record of the participants' feedback and insights.

Following the interviews, the next step was a collaborative lesson plan where notes were taken. This method was essential as it directly applied the insights gained from the initial semi-structured interviews. The researcher worked with the participants to create a lesson plan that was tailored to their specific context and needs. This collaborative process ensured that the lessons were relevant and meaningful to the participants. The notes taken during this session documented the decisions made and the rationale behind the lesson's design. This was a crucial bridge between the initial, more theoretical stage of data collection (interviews) and the practical, observational stages (teaching and video recording the lessons).

The first lesson taught at each of the three schools was video recorded. This was a logical next step as it provided a direct observation of the lesson in action. The video recordings captured the real-time interactions, teaching strategies, and learner engagement. This method provided a rich, detailed record of what happened during the lesson, offering a different and more objective perspective compared to the self-reported data from the interviews. The video recordings served as the basis for the subsequent interviews and reflections, allowing the participants to recall and analyse specific moments from the lesson.

Interviews based on the first lesson taught were the next data collection method, and they were audio recorded. This was a necessary step to get the participants' perspectives and reflections on the first lesson. The researcher could ask specific questions about interactions by using the video recordings of the lesson as a reference point. This process allowed for a deeper understanding of the participants' thought processes and the decisions they made during the lesson. The audio recordings provided a detailed account of these discussions.

After the interviews about the first lesson, the researcher taught a second lesson in each of the three schools, which was also video recorded. This step was crucial for observing how the researcher applied the insights and reflections gained from the first lesson and subsequent interview. It allowed the researcher to see if there were any changes or improvements in teaching strategies. The video recordings of the second lesson provided another data set for analysis and comparison with the first lesson.

Finally, the study concluded with reflection sessions based on the second lesson, which were audio recorded. This last step was essential for capturing the participants' final thoughts and reflections on the entire process. It provided a space for them to analyse their experience and reflect on their growth throughout the study. The audio recordings captured the final thoughts and a concluding view on the research process and its results.

3.5.1 Lesson planning

A lesson plan is a description of a teacher's lessons for a particular topic. It often consists of objectives, teaching materials, methods, and assessments. Teachers who create a lesson plan can make certain that each lesson is organised, focused, and linked with learning objectives (Farhang et al., 2023). A well-designed lesson plan can assist teachers in providing successful and interesting classes that encourage learners to learn.

The collaborative lesson planning amongst the researcher and the three participating teachers was done prior the first lesson, aiming to understand each teacher's individual pedagogical content knowledge and preferred smartboard affordances. This interview session was crucial for assessing how these individual preferences would influence the group's collective PCK and the overall selection of smartboard affordances for the lessons. The researcher could determine whether and how their personal PCK and preferred smartboard affordances impacted the collaborative decisions and ultimately shaped the lesson's design and execution by examining the teachers' individual approaches.

The researcher employed a strategy to engage teachers in the planning process for two lessons. This involved a combination of virtual meetings, leveraging both Teams and WhatsApp platforms. To accommodate the diverse schedules of the three participating teachers, all meetings were scheduled for 18:00. The initial planning phase commenced after the first interview session that was done on the 6th of June 2024, with a Teams meeting. This meeting was audio-recorded to ensure a detailed record of the discussions. Subsequent planning sessions were conducted through WhatsApp video calls, taking place on June 19, June 27, and July 12. While these meetings were not recorded, notes were taken to capture the key points and decisions made. The meetings were not recorded to ensure that there was a more natural and open environment for discussion. Recording the sessions could have made the three participating teachers feel self-conscious or inhibited, potentially altering their behaviour and leading to less genuine interactions. The researcher's presence and detailed notetaking provided a less intrusive way to capture the essential data without the potential for discomfort that a recording device might cause. This approach prioritized the comfort and understanding with the participants.

During the planning process, the three participating teachers and the researcher agreed that they will not have an actual lesson plan but will make use of a PowerPoint presentation that was significantly influenced by the components of the Refined Consensus Model of PCK and SAMR Model as depicted in Figure 6. The two PowerPoint presentations were used instead of a traditional lesson plan to facilitate a more interactive and visually driven collaborative process. A PowerPoint presentation provides a structured, yet flexible, platform that allows for integration of smartboard affordances such as annotations, visual aids (pictures, diagrams, videos) and sequential flow during the planning process. In other ways, the PowerPoint presentations served as a visual aid during the planning session, helping the three participating teachers and researcher to collectively visualize the lesson's progression and discuss specific elements, such as when to use a particular smartboard affordance or how to sequence activities.

After data had been collected from the first two schools, an additional meeting was held on August 29th with three teachers to address the specific implementation of the Mentimeter tool and Google Site. This separate session was necessary because the use of these specific digital tools was a later development, occurring after data collection had already been completed at the first two participating schools as depicted in Figure 7 and Figure 8.

The researcher participated in the lesson planning process to gain an insider's perspective and a deeper understanding of the three participating teachers' decision-making processes. This participation was a form of participant observation, which is a common qualitative research method. The researcher was able to observe firsthand how teachers co-constructed knowledge and negotiated the integration of smartboard affordances and pedagogy by being present and engaged in the process. If the teachers had planned the lessons without the researcher's presence, the researcher would have lacked this direct insight. The data would have been limited to the final lesson plans and teacher reflections, missing the contextual details of the collaborative process itself.

This data collection method helped to answer the following research questions:

- How do teachers integrate smartboard affordances with pedagogy when teaching photosynthesis in the grade 11 life sciences classroom?
- What steps can teachers follow to integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?

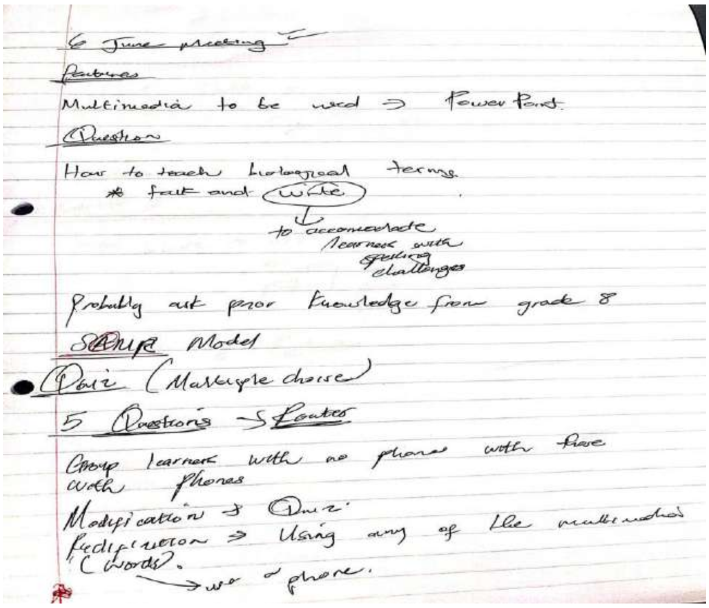

Figure 6: Notes from lesson planning from the 6th of June 2024.

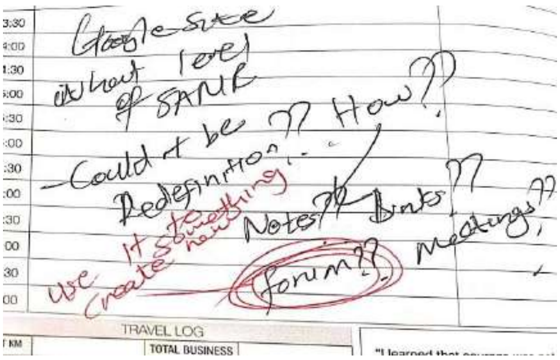

Figure 7: Notes taken from lesson planning from the 29th of August 2024.

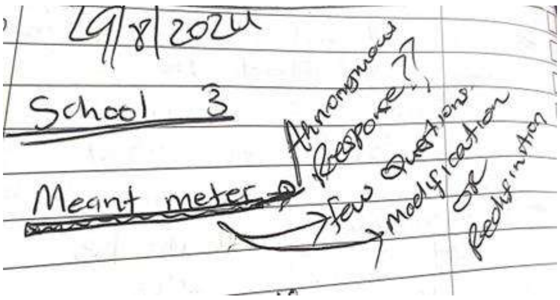

Figure 8: Notes taken from lesson planning from the 29th of August 2024 on Mentimeter.

Figure, 6, 7, and 8 depict notes that were taken by the researcher during the planning process. These notes were taken by the researcher to ensure that the data is not selectively filtered or interpreted by the participating teachers, who might naturally focus on what they perceive as most important or relevant to their own teaching practice. In other words, the participating teachers may focus on different aspects of the discussion, potentially omitting details that are relevant to the research question.

Furthermore, the notes were taken to provide a tangible record of the discussions and decisions that underpin the planned lessons. These notes captured the ideas between the researcher and the three participating teachers, documenting how they will collectively integrate pedagogical strategies with smartboard affordances to teach photosynthesis. Notetaking captures the co-construction of knowledge and the reasoning behind specific teaching methods. This approach ensures that the researcher has an honest representation of the group's discussions and decisions which is important for examining how teachers' collaboration influences the integration of smartboard affordances and pedagogy.

The extent to which the researcher influenced the results was a crucial consideration. The researcher's presence and note-taking unavoidably introduced a degree of influence. The three participating teachers may have altered their behaviour or ideas, consciously or unconsciously, knowing they were being observed. However, the researcher's goal was to minimize this influence through a conscious effort to adopt a non-directive and unobtrusive role.

Table 4: A summary of the smartboard affordances selected during the planning process and used d the lessons.

Smartboard affordance	Description of a smartboard affordance, how it was used and why it was used.
Writing and Highlighting on the smartboard	This affordance was used by learners and teachers to directly annotate their desktop with digital ink. They were able to switch between various colours and utilize a highlighter to emphasize key sections of text or images. The pen tool was used for visual clarity since it offered customization options for size, colour. A digital eraser was also used for quick removal of annotations.
Touch sensitivity	Teachers were able to use this affordance to write, draw, annotated, highlight, play, pause video, and safe work.
Timer	The timer allowed the teachers to manage the duration of activities and segments within a lesson. The timer was set with audible alerts to signal the end of a designated time.
Animation video	The animation video allowed the teachers to create a dynamic visual effect.
Saving work	The teachers were able to save any work that was done on the smartboard to the smartboard and a USB.
Internet connectivity	Teachers used this affordance to access google to login into emails.
IQ Interactive Education Platform.	Teachers used this affordance to facilitate the learners' learning activities by developing and delivering engaging visual presentations.
Digital Document Presentation	Teachers displayed and annotated notes from a PowerPoint presentation.
Interactive Learning Activities	Teachers engaged learners in interactive exercises, a 30-second game to reinforce learning

Table 4 lists and describes various smartboard affordances such as writing, touch sensitivity, and internet connectivity, detailing how teachers and learners used them during photosynthesis lessons. This table is important because it clearly outlines the specific affordances and pedagogical applications of smartboard technology, highlighting how these affordances can be leveraged to enhance teaching and learning.

3.5.2 Semi-structured interview

This research adopted a methodological framework encompassing the diverse instruments, procedures, and strategies employed for data acquisition, analysis, and interpretation (Jackson et al., 2007). Additionally, Ndlovu (2021) conceptualizes interviews as an interactive data collection technique involving dialogues between two or more individuals, facilitated by a sequential exchange of questions and responses aimed at gleaning pertinent information. Ndlovu (2021) further highlights the versatility of interviews, acknowledging the application of structured, semi-structured, and unstructured Olenik question formats. This study used semi-structured interviews typically focusing on a central research question to illuminate broader patterns (Ruslin et al., 2022). Semi-structured interviews offer inherent flexibility. This adaptability allows for the emergence of follow-up inquiries organically prompted by the interviewee's responses (Ruslin et al., 2022). Consequently, to ensure alignment with the research objectives, semi-structured interviews rely on open-ended questions outlined in an interview guide (Adeoye-Olatunde & Olenik, 2021).

Regarding this, there were two interview sessions and one feedback session for each teacher from each of the three secondary schools within the Gauteng District (see Appendix 14). The first interview was conducted before the lesson planning process; the second interview was conducted after the first lesson was taught and feedback session was sone after the second lesson was taught. The questions asked during the interview conducted prior the lesson planning process were different from the questions that were asked after the first lesson and during the feedback session. This means that, the questions that were asked served as a lens to identify the teacher’s pedagogical reasons behind the routines that they followed to integrate smartboard with the pedagogy as they were teaching photosynthesis in the grade 11 life sciences classroom.

The refined consensus model of PCK and the SAMR model were used to design the research questions for the three teachers, and all the three teachers were asked the same questions. The interviews were documented through audio recordings for subsequent analysis as qualitative data. This approach facilitates verbatim capture of participant responses, enhancing the accuracy and depth of the data for subsequent thematic analysis (theme identification) and interpretation. This methodology facilitates a deeper understanding of how grade 11 life sciences teachers integrate smartboard into their pedagogical strategies during photosynthesis lessons.

Table 5: A summary of the interviews conducted in three schools (see appendices 15,16,17,18,19,20,21,22,23 for a sample of semi-structured interview transcripts from all participating schools).

School Name	School 1	School 2	School 3
Date and duration of the interview prior the lesson planning process	27 May 2024 6:36 mins	30 May 2024 5:39 mins	4 June 2024 7:27 mins
Date and duration of the interview after the first lesson	13 July 2024 11:46 mins	14 July 2024 13:06 mins	30 August 2024 16:10 mins
Date and duration of the feedback session after the second lesson	13 July 2024 12:06 mins	14 July 2024 12:52 mins	30 August 2024 14:03 mins

Table 5 outlines the dates and durations of interviews and feedback sessions conducted with teachers from three different schools. This table is important as it provides a clear timeline and record of the research process, demonstrating a structured approach to data collection across the three participating schools.

This data collection method helped to answer the following research questions:

- How do teachers integrate smartboard affordances with pedagogy when teaching photosynthesis in the grade 11 life sciences classroom?
- What steps can teachers follow to integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?

3.5.3 Participant observation

This research employed participant observation, a qualitative data collection method where researcher actively engage in the routine activities of a specific social setting (Shin & Miller, 2022). This embedded approach allows for the examination of a particular facet of social life within its natural context (Busetto et al., 2020). In essence, the researcher assumed a dual role, simultaneously participating in the setting while observing and collecting data on behaviours and interactions of the participants. This research utilized participant observation to explore the integration of smartboards within pedagogical practices for teaching photosynthesis to grade 11 learners. The researcher actively participated in lesson planning sessions with teachers, gaining insights into their approaches to identify and document potential steps that teachers can follow when integrating smartboards with pedagogy during photosynthesis lessons.

Regarding this, the teacher taught one lesson in each school. This granted the researcher access to richer data, encompassing not only teacher-learner interactions but also the effectiveness of the smartboard technology within the specific classroom environment. This experience was important for data triangulation since it helped to strengthen the study's findings by comparing the researcher's personal teaching experience with the teachers' experiences. This process helped validate the initial observations and provided an understanding of the topic, reduced biases that could have arisen from relying on a single data source.

As already stated, the researcher was part of the setting that she was studying while also observing and collecting data. In each of the three participating schools there were two lessons taught. Each teacher from each of the three participating schools taught the first lesson (lesson 1) on photosynthesis which the researcher observed. This allowed the researcher to observe their teaching strategies (personal PCK) and see how they implemented the strategies they had collaboratively planned (enacted PCK). This provided valuable insights into the teachers' pedagogical practices and their comfort level with integrating smartboard affordances. In other words, this offered a clear view of how the teachers' planning translated into classroom practice.

The second lesson (Lesson 2) was taught by the researcher in each of the three participating schools. This provided a firsthand opportunity to experience the practical benefits and challenges of integrating smartboard affordances with pedagogy. The researcher gained an understanding of the difficulties and benefits that teachers face when using the smartboard affordances in the classroom. This was a form of participant observation, allowing the researcher to collect data from a unique insider's perspective. This experience was crucial for data triangulation. Through comparing the researcher's personal teaching experience with the teachers' experiences, the study's findings were strengthened. This process also helped validate the initial observations and provided a more understanding of photosynthesis, reducing potential biases that could arise from relying on a single data source.

For the entire study there were six lessons and there were two observational tools that were used one observational tool was informed by the Refined Consensus Model of PCK and the other observational tool was informed by the SAMR model. The PCK model was used to analyse teacher effectiveness across two phases: lesson planning and lesson delivery. During planning, the researcher observed the collective PCK, focusing on aspects like collaborative decision-making, pedagogical reasoning, content accuracy, and alignment with curriculum documents (CAPS and ATP). During the lesson, the focus shifted to personal and enacted PCK, observing real-time pedagogical decisions, classroom context, content delivery, and assessment practices. The SAMR model, conversely, was used to track the level of smartboard affordances integration, specifically observing how teachers utilized smartboard functionalities such as writing, drawing, displaying simulations, annotating diagrams, using presentations, and sharing resources via QR codes, thereby determining the degree to which the smartboard is transforming or simply substituting traditional teaching methods.

Basically, the observational tools were used to find out how teachers integrate smartboard affordances with pedagogy during the photosynthesis lesson and to measure the effectiveness of integrating smartboard affordances to teach photosynthesis in the grade 11 classroom. The effectiveness of using smartboard to teach life sciences was measured by how frequently the components of each framework was used and how they were used. The order in which the components of the SAMR model was used will help in identifying any possible routines that teachers must follow to integrate smartboard with pedagogy in the classroom.

This data collection method helped to answer this research question:

- To what extent did the teachers integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?

3.5.4 Video recording

This research project leveraged video recording as its mode of data collection. According to Ukkonen-Mikkola and Ferreira (2022) video recordings are recognised as a valuable source of empirical data that capture a wide range of observable aspects, such as actions, verbal exchanges, social dynamics, material culture, and behaviours. Therefore, during the lesson observations, the researcher conducted video recordings of all three teachers' lessons using a smartphone camera. Additionally, a reciprocal recording arrangement was established, whereby each teacher was asked to record the researcher during their designated instructional segments. Reason for this, video recordings offer a distinct advantage in capturing the intricacies of how teachers and learners behave and interact with each other. The recorded data provided a rich source of material for subsequent analysis, allowing for a nuanced understanding of how to integrate smartboard with pedagogical methods during photosynthesis lesson in the grade 11 classroom. Furthermore, video recordings offered the benefit of permanence. Unlike fleeting observations, the data can be revisited and reviewed multiple times (Andreae, 2021). In agreement to this, the video recordings can facilitate a rigorous analysis.

This data collecting method helped to answer the following questions:

- How do teachers integrate smartboard affordances with pedagogy when teaching photosynthesis in the grade 11 life sciences classroom?
- To what extent did the teachers integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?

Table 6: A summary of lessons observed by the researcher and taught by the researcher (see appendices 8, 9, 10, 11, 12, 13 for lesson observational transcripts from video recordings).

School Name	School 1	School 2	School 3
Dates in which the lessons were taught	13 July 2024	14 July 2024	30 August 2024
Lessons taught	**Lesson 1-**Photosynthesis. **Lesson 2-** Starch test: experiment.	**Lesson 1-**Photosynthesis. **Lesson 2-** Starch test: experiment.	**Lesson 1-**Photosynthesis. **Lesson 2-** Starch test: experiment.
Instructor of each lesson	**Lesson 1-** Jade **Lesson 2-** Researcher	**Lesson 1-** Samantha **Lesson 2-** Researcher	**Lesson 1-** Zandaya **Lesson 2-** Researcher
Duration of each lesson	**Lesson 1-** 1:08:38 mins **Lesson 2-** 53:38 mins	**Lesson 1-** 50:20 mins **Lesson 2-** 46:48 mins	**Lesson 1-** 50:05 mins **Lesson 2-** 57:19 mins

Table 6 provides a summary of the lessons taught at three different schools, including the dates, lesson topics, instructors, and duration.

3.6 Visiting the three schools.

The researcher collected data at three schools over a period of two months. Data collection commenced on July 13, 2024, at the first school, followed by the second school on July 14, 2024, and concluding at the third school on August 30, 2024. Upon arrival at each school, the researcher was warmly welcomed by the participating teacher. The research design entailed two lessons being delivered on the same day in each school. To ensure adequate preparation time, the researcher and teachers arrived 30 minutes prior to the learner's scheduled arrival at 7:30 AM to conduct the initial interview. Before the commencement of the first lesson, a semi-structured interview was administered in each school, encompassing five identical questions. The interviews were successfully completed within a timeframe of 7:40 to 7:45 AM in each school. As the clock struck 7:50 AM, learners began to arrive, with the majority arriving punctually.

To capture the first lesson from various perspectives, the researcher utilized both her smartphone and the teacher's smartphone for recording. The duration of the first lesson varied across schools, lasting 1 hour and 8 minutes at the first school, 50 minutes and 20 seconds at the second school, and 50 minutes and 5 seconds at the third school. Although the lessons were initially planned to be approximately 45 minutes, the active engagement of the learners contributed to an extended duration. Following the first lesson, learners were granted a 15-minute break, during which the second semi-structured interview was conducted with the teachers. The questions posed in this interview were tailored to the specific content of the preceding lesson, with the first school receiving five questions, the second school receiving six questions, and the third school receiving four questions.

Upon the conclusion of the 15-minute break, learners returned, and the second lesson commenced, this time taught by the researcher. The duration of the second lesson also varied, with the first school taking 53 minutes and 38 seconds, the second school taking 46 minutes and 48 seconds, and the third school taking 57 minutes and 19 seconds. After the completion of the second lesson, learners were dismissed, and the feedback session was conducted, involving all three participating teachers respectively. However, due to the use of MentiMeter during the lesson, the third school required additional questions to be addressed during the feedback session. The questions asked during the feedback session after the second lesson focused on the researcher's teaching and were completed within a shorter timeframe than anticipated, taking less than 15 minutes in each school.

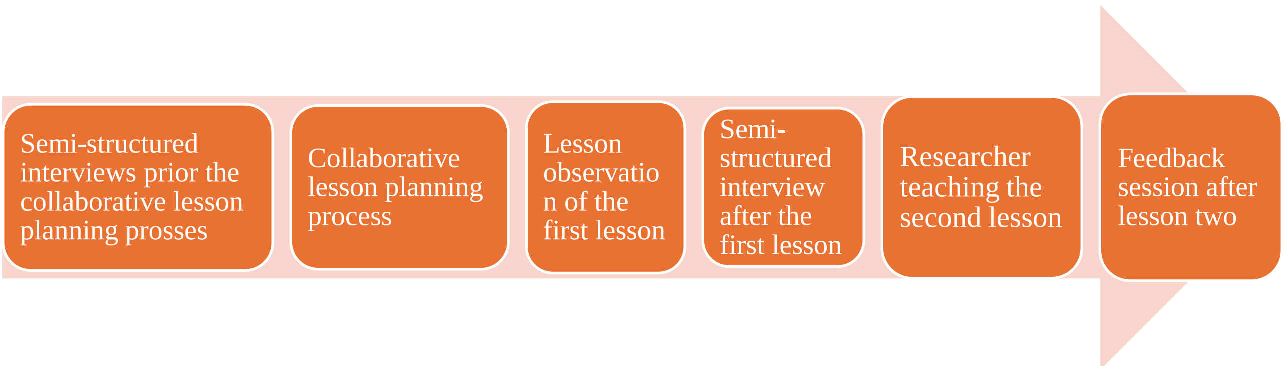

Figure 9: A summary of how data was collected.

Figure 9 shows a sequential research methodology for studying teaching, starting with semi-structured interviews and collaborative planning, followed by lesson observations, and concluding with a second lesson taught by the researcher and a feedback session. This figure is important because it visually represents a clear, systematic process for data collection and analysis.

3.7 Data analysis

3.7.1 Coding and theme identification

In qualitative data analysis, coding is a step where researchers organize and categorize non-numerical data to identify patterns and themes. This process can be inductive, drawing codes directly from the data (e.g., participant quotes), or deductive, using a predetermined framework to guide code development (Adeoye-Olatunde & Olenik, 2021). Inductive coding, in theme identification, allows themes to naturally arise from raw data by analysing data closely, generating initial codes, and then refining them into higher-level themes, ideal for exploring new areas (Skjott Linneberg & Korsgaard, 2019). Deductive coding, conversely, uses pre-defined codes from existing theories to test or refine them, providing focused analysis but potentially missing new patterns. Skjott Linneberg and Korsgaard (2019) further explain that a combined approach, or abduction, blends these methods, allowing researchers to discover themes inductively while also grounding them in existing theories deductively, enhancing the overall theme identification process by cycling between data and theory.

The study employed a deductive approach since the analysis focused on identifying instances that illustrated the levels of SAMR model and the refined consensus model of PCK in action, while attempting to understand the teachers pedagogical reasoning as it manifested in their classroom practice. The process of integrating and synthesizing these codes culminates in theme analysis, offering a coherent understanding of the findings (Adeoye-Olatunde & Olenik, 2021). The process began with pre-collaborative lesson planning interviews. The researcher listened to the audio recordings of these interviews twice, transcribed them on the third listen, and then verified the accuracy of the transcripts. Subsequently, the interview transcripts were coded using the refined consensus model of PCK. Following this, the SAMR model was applied to identify specific smartboard affordances mentioned within the transcripts.

Next, the researcher proceeded to analyse the first lesson. Video recordings of the initial lesson from each of the three schools were and listened to twice and then transcribed. The transcripts were again verified by and listening the videos a third time. The transcripts were then coded using the refined consensus model of PCK, and the SAMR model was then used to identify the affordances of the smartboard as shown in the lesson. Following the first lesson, post-lesson interviews were conducted. The audio recordings of these interviews were listened to twice, transcribed on the third listen, and verified for accuracy. The transcripts were then coded using the refined consensus model of PCK as a lens, and the SAMR model was used to identify level of integration of the smartboard affordances.

The researcher then proceeded to analyse the second lesson. Video recordings of the second lesson from each of the three schools were and listened to twice and then transcribed. The transcripts were again verified by and listening the videos a third time. The transcripts were then coded using the refined consensus model of PCK, and the SAMR model was then used to identify the affordances of the smartboard as shown in the lesson. Finally, post-second lesson interviews were conducted. The audio recordings of these interviews were listened to twice, transcribed on the third listen, and verified for accuracy. The transcripts were then coded using the refined consensus model of PCK, and the SAMR model was used to identify smartboard affordances. This systematic process of coding and analysing interview transcripts and lesson video recordings, using both the refined consensus model of PCK and the SAMR model, facilitated the identification of themes related to teachers' use of smartboard affordances in teaching photosynthesis.

3.7.2 Narratives Enquiry

Narrative enquiry is a method used to understand human experiences of a specific event or phenomenon by examining the stories shared by the individuals who lived through it. It involves taking the raw accounts of experiences and transforming them into organized and meaningful narratives that can be understood by others (Chand, 2024). During this research on the integration of smartboard affordances in Grade 11 photosynthesis lessons, the researcher employed narrative inquiry as a data analysis method.

3.7.2.1 Development of narratives

Initially, the researcher listened closely to the interview audios conducted before the collaborative lesson planning sessions across the three schools. Through this process, the researcher was actively listening to the teachers' views on teaching of photosynthesis, their pedagogical reasoning related to photosynthesis instruction, and their considerations on the use of the smartboard. Guided by the SAMR Model and the refined consensus model of PCK, the researcher developed narratives on how teachers plan their teaching of photosynthesis. See sections 4.1.1, 4.1.2, and 4.1.3. Following this, the researcher moved to the video recordings of the first lesson that was taught by the three participating teachers across the three schools respectively. Here, narrative inquiry allowed her to go beyond simply observing classroom interactions. She watched and listened to the video recordings for three times, paying close attention to the unfolding observations of the lessons; how the teachers presented the content, how the learners engaged with the smartboard affordances and the concepts, and the implicit stories of teaching and learning that emerged. The researcher's narratives focused on identifying instances that illustrated the levels of the SAMR Model and the refined consensus model of PCK in action, while also attempting to understand the teachers' pedagogical reasoning as it manifested in their classroom practice. See sections 4.3.1, 4.3.2, and 4.3.3.

Subsequently, the researcher returned to the interview audios, this time those conducted after the first lesson. The researcher listened for how their initial understandings and anticipations had been confirmed or challenged by the actual implementation of the lesson. She sought to identify shifts in their pedagogical reasoning, their insights into the affordances and limitations of the smartboard, and how they perceived the impact on learner learning. Again, the researcher illustrated the levels of the SAMR Model and the refined consensus model of PCK in action, while also attempting to understand the teachers' pedagogical reasoning as it manifested in their classroom practice. See sections 4.4.1, 4.4.2, and 4.4.3.

The process continued with the video recordings of the second lesson that was taught by the researcher across the three schools. Here, narrative inquiry allowed the researcher to explore the evolving stories of the lessons themselves, noting any changes in teaching approaches, learner engagement, and the integration of the smartboard. The researcher also examined how her own pedagogical reasoning, shaped by her past teaching experiences, became evident in their instructional methods when she was teaching the learners. Furthermore, the researcher's narratives continued to focus on drawing out narratives that illustrated the levels of the SAMR Model and the refined consensus model of PCK. See sections 4.5.1, 4.5.2, and 4.5.3.

Finally, the researcher listened to the feedback session audios conducted after the second lesson. The researcher listened for the stories of how her understanding of the integration of smartboard affordances evolved and her pedagogical growth. The researcher's narratives continued to focus on drawing out narratives that illustrated the levels of the SAMR Model and the refined consensus model of PCK. See sections 4.6.1, 4.6.2, and 4.6.3. Through this iterative process of listening to audio recordings and watching video recordings the researcher aimed to gain a deep and nuanced understanding of the teachers' experiences and the impact of smartboard affordances on their Grade 11 photosynthesis lessons.

3.7. 3 Reflective Analysis

The researcher engaged in a detailed reflective analysis of the video recordings from the second lesson across the three participating schools. This stage was crucial for identifying patterns, differences, and the evolution of the researcher’s pedagogical approaches in relation to the integration of smartboard affordances. The researcher reviewed each of the three videos, paying close attention to instances where the smartboard affordances were integrated. This involved not only observing the apparent use of the technology but also inferring the underlying pedagogical reasoning that guided the researcher’s choices.

Furthermore, the researcher revisited the framework of the SAMR Model and the refined consensus model of PCK while analysing the video data. She looked for concrete examples within the lessons that illustrated different levels of SAMR Model and the refined consensus model of PCK. This involved categorizing specific teaching moments and learner interactions based on these theoretical frameworks, providing a structured lens through which to understand the impact of the smartboard affordances. This reflective process allowed the researcher to develop a more nuanced understanding of the complex interplay between the integration of smartboard affordances, pedagogy, and content knowledge in the context of Grade 11 photosynthesis instruction. The aim of looking back at the lessons closely was not just to say what happened. Instead, the researcher wanted to figure out the reasons why things happened the way they did thereby contributing to a deeper understanding of the integration process.

3.8 Establishing rigor

Rigor cannot be guaranteed to have been achieved, but the researcher made effort to maximise it. While participant observation provides valuable, in-depth data, its trustworthiness can be compromised by inherent subjectivity. Though techniques like member checking can address this, the accuracy of the feedback may be hindered by social desirability bias, power dynamics, and participants’ potential misunderstandings (Ahmed, 2024). However, the researcher's initial power dynamic was mitigated through a collaborative observation model involving the three teachers. This approach ensured that the researcher's actions and decisions were subjected to the group's collective scrutiny, fostering a more balanced and equitable process for data collection and analysis.

Jackson et al. (2007) propose that qualitative research prioritizes establishing trustworthiness, encompassing credibility, transferability, dependability, and confirmability, as opposed to traditional metrics like validity, reliability, and objectivity. This study adhered to this framework, employing member checking, a technique where participants validate the accuracy and resonance of findings for credibility (Adeoye-Olatunde & Olenik, 2021). In essence, member checking serves as a mechanism for qualitative research validation by circulating themes and descriptions to participants for confirmation of their authenticity (Jackson et al.,2007). This means that throughout the lesson observations, validation was a continuous process since the researcher was part of the participants. Following lesson observations, the researcher, acting as a participant observer, would debrief with the teachers to confirm the accuracy of their observations. For example, after observing a lesson where a teacher Zandaya used the smartboard to display a diagram of a chloroplast and then annotated (as depicted in figure 22) it with the different stages of photosynthesis, the researcher would later ask the teacher to confirm if the annotations were intended to represent the light-dependent and light-independent reactions. This approach ensured that the researcher's interpretation of the teachers' pedagogical decisions and actions was authentic and aligned with the teachers' original intent.

In qualitative research, ensuring transferability, the applicability of findings to other contexts, is crucial (Göçen et al., 2020; Stahl & King, 2020). Researchers achieve this by providing rich, detailed descriptions of the research setting and participant experiences (Göçen et al., 2020). For example, this study aimed to identify possible routines for teaching photosynthesis to grade 11 learners through the integration of smartboards and pedagogy, detailed descriptions of those routines should be provided in chapter five. This allows teachers in other schools to consider and potentially adapt these routines for their own contexts. This can be seen in chapter five of this study. Dependability, the consistency, and neutrality of the research process is another key quality consideration (Göçen et al., 2020). Researchers establish dependability by maintaining audit trails, which document the research process in sufficient detail (Maher et al., 2018). These detailed records allow other researchers to replicate the study and potentially achieve similar results. The researcher has detailed documentation of the entire research process.

Confirmability, analogous to objectivity in quantitative research, seeks to minimise researcher bias (Maher et al., 2018). One strategy to achieve confirmability is to involve another researcher in reviewing and responding to the field notes, including the researcher's interpretations (Stahl & King, 2020). However, since the researcher was one of the participants, she involved the participating teachers to review the findings. This collaborative process helped to identify and address potential biases that may be embedded within the researcher's perspective, which in this case were not found.

3.9 Ethical consideration

Vithal and Jansen (2019) posit that ethical research necessitates participant safeguard and researcher integrity. Participant safeguard entails minimizing potential harm throughout the research process. Informed consent plays a crucial role, ensuring participants are fully apprised of the research's objectives, potential outcomes, and data utilization (Vithal & Jansen, 2019). The researcher has applied for and obtained ethical clearance from Wits HREC and asked permission to conduct the study from Gauteng department of education, asked permission from three secondary school’s principals, provided each school with the consent letters, and participants information letters. This means the researcher obtained permission from the school, the three participating schools, learners parents given that they are minors and the learners.

Furthermore, anonymity and confidentiality measures were put in place to preserve participant identities. During the semi-structured interviews, participants were assigned pseudonyms, and any identifying details, such as their names, the names of their schools, or specific locations, were omitted from transcripts. The audio recordings themselves, which were stored on password-protected and encrypted devices, were accessible only to the primary researcher. This ensured that even if a breach occurred, the data would be unintelligible. Furthermore, the researcher's role as a participant observer involved capturing visual data such as video recordings, but specific precautions were taken to protect identities. All participants, including the three teachers and some learners, were careful to turn their backs to the camera during video recordings. In instances where a participant's face did appear on video, the researcher used emojis to obscure their identity. This approach ensured that no one could be individually identified in the visual data. Both the audio and video recordings, despite being saved on an encrypted password-protected device, will be permanently deleted after three years. Researchers were able to uphold the research's integrity and foster its trustworthiness by adhering to these ethical principles (Vithal & Jansen, 2019).

3.10 Conclusion

The current chapter provides an exploration of the research methodology and design that was employed within the study. It detailed the data acquisition methods, the ethical considerations, and the specific research tools that were utilized to ensure the integrity and rigor of the investigation.

Chapter 4

Findings and discussions

4. Introduction

This chapter aimed to address the research questions by analysing how teachers integrate smartboard affordances to teach Grade 11 Life Sciences learners photosynthesis across three Gauteng secondary schools. To achieve this, a deductive coding approach was employed. Guided by the refined consensus model of PCK and the SAMR model, the analysis compared data from lesson transcripts, and interviews. This process served to validate and refine the findings. The iterative nature of cycling between data and theory, as recommended by Adeoye-Olatunde & Olenik (2021), facilitated an understanding of the teachers' practices. The research questions that this study aims to answer are as follows:

- **Primary question**

The main question the study sought to address was:

1. How do teachers integrate smartboard affordances with pedagogy when teaching photosynthesis in the grade 11 life sciences classroom?

- **Secondary questions**

The following secondary research questions were developed to further organise the researcher's trajectory in addressing the main research question:

1. To what extent did the teachers integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?
2. What steps can teachers follow to integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners?

Interview transcripts and video transcripts

The researcher had already obtained the transcripts of the audio recordings from her smartphone, which was used to record the interviews. To ensure accuracy, she listened to the recordings two more times to verify that the transcribed dialogue matched the audio. For the video recordings, the researcher had to transcribe them manually by watching, listening, pausing, and typing the dialogue. After the initial transcription, she listened to the video recordings two more times to confirm the transcript's accuracy.

4.0 Data analysis and presentation of findings

As indicated in chapter 3 section 3.7, collected data was analysed and findings presented in the following order to bring out a coherent story from this study as depicted in Figure 10. This figure shows a flow chart that outlines the key stages of data analysis, it provides a clear, structured plan for organizing and presenting the research findings, ensuring all key parts of the study are addressed in a logical sequence.

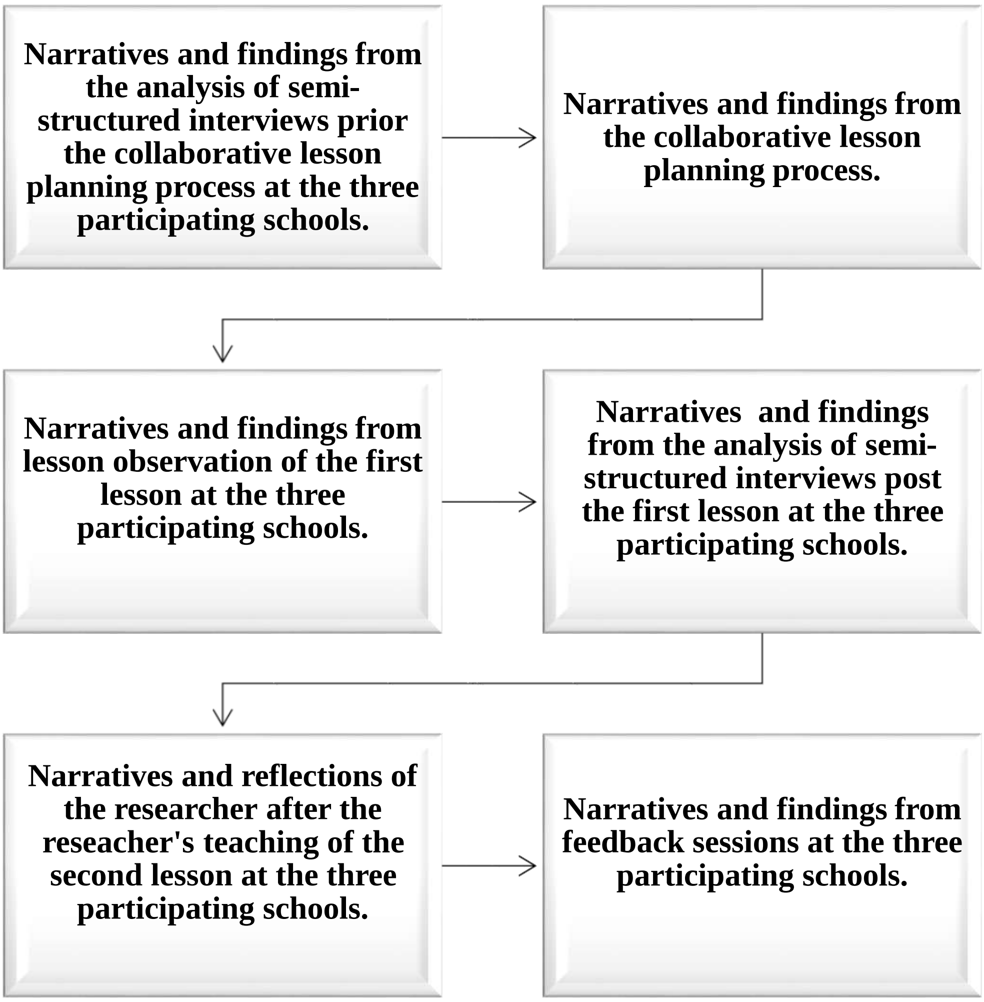

Figure 10: The order of data analysis and findings

4.1 Analysis of transcripts of prior lesson planning process interviews.

After a thorough three-time listening process for each interview, the researcher transcribed the audio. With all interviews transcribed, she then created individual narratives for each one. The researcher had used her smartphone to record the interviews, so the transcriptions were already on the device. Her task was to listen again to the recordings to confirm that the dialog in the transcripts accurately matched the audio.

4.1.1 Narratives from the interview with teacher Jade.

Jade's responses revealed a teacher who, despite infrequent smartboard use due to technical issues, recognizes its potential to enhance learning through visual engagement. This reflects a substitutional level of the SAMR Model, where this technology can be used as a direct substitute for traditional methods, in this case, using the smartboard for visual presentation. She indicated in the interview that she primarily utilizes the smartboard's writing and highlighting affordances through the IQ Interactive software to dynamically illustrate complex concepts and diagrams, demonstrating a focus on personal PCK. This can be viewed as moving towards augmentation, as the smartboard provides enhanced affordance compared to traditional chalkboards, enabling dynamic annotation. This demonstrates her personal PCK, as she is utilizing her own understanding of how to use the smartboard affordances to improve her teaching.

Her teaching approach for photosynthesis begins with an engaging visual to activate prior knowledge and capture learner attention, followed by interactive annotation of diagrams to explain processes and components, showcasing her understanding of how to use the smartboard affordances to support her pedagogical goals. This further solidifies the augmentation level, as the interactive elements enhance the teaching process. Regarding learner misconceptions, Jade identified confusion between chlorophyll and chloroplast functions and photosynthesis and cellular respiration. To address these, she explained that she uses the smartboard for side-by-side comparisons and visual diagrams, demonstrating her content knowledge by differentiating these concepts. This continues to align with augmentation, as the smartboard allows for more dynamic and visually engaging comparisons than traditional methods. Her content knowledge is evident in her ability to accurately differentiate these concepts, and her pedagogical knowledge is shown through her use of visuals and interactive annotation.

She also explained that she uses gamified quizzes and simulation software on the smartboard to facilitate learner collaboration and discussion, though she acknowledges limited use of other interactive features like polls. This introduction of gamified quizzes and simulations points towards modification, as the technology allows for a significant redesign of the learning activity. This usage of gamified quizzes and simulations demonstrates her assessment knowledge and curricular knowledge, as she is using tools to evaluate learner understanding and align with curriculum goals. Her knowledge about her learners is shown by her attempt to increase collaboration and discussion. In general, Jade sees the smartboard as a tool to improve visual learning and clarify complex biological processes, even though her usage is somewhat limited by technical constraints. This indicates that while there are elements of modification, the primary use remains within the substitution and augmentation levels of the SAMR model. The limitations caused by technical issues showcase the learning context, which influences her enacted PCK.

4.1.2 Narratives from the interview with teacher Samantha.

Samantha primarily utilizes the smartboard affordances in Grade 11 and 12 classrooms due to the abstract nature of the content, which benefits from visual representation. This reflects the substitution level of the SAMR model, where the smartboard is used as a direct substitute for traditional teaching methods, like using a chalkboard or overhead projector, to display visual aids. The teacher mentioned that she favours PowerPoint presentations for their ease of editing and annotation, allowing for lesson continuity and improvement. This moves towards augmentation, as the smartboard and PowerPoint enhance the teaching process by providing editable and annotatable visual aids, which goes beyond simple substitution by adding functional improvement. Samantha's personal PCK is evident in her preference for PowerPoint, reflecting her individual understanding of how the smartboard affordances can represent abstract concepts. This personal knowledge is built upon her pedagogical knowledge of visual learning and her content knowledge of the subject matter.

The smartboard is instrumental in teaching photosynthesis by enabling the display of enlarged chloroplast structures, facilitating the explanation of light and dark phases. Samantha addresses learner misconceptions about these phases by visually differentiating the chloroplast components and demonstrating the interconnectedness of the phases' products. This represents modification within the SAMR model. The smartboard and PowerPoint are not merely replacing traditional methods but are being used to fundamentally modify the teaching approach by enabling dynamic visual representations that directly address and clarify complex concepts, like photosynthesis, in a way that would not be as effective with traditional means. This highlights her knowledge of the learners, as she tailors her teaching to address specific learner difficulties. This is also demonstrating enacted PCK as she is actively using the smartboard affordances to improve understanding while teaching.

To foster collaboration, Samantha mentioned that she employs interactive smartboard activities like crossword puzzles for vocabulary reinforcement and labelling exercises for chloroplast structures, combining technology with assessment and pedagogical strategies. This demonstrates redefinition within the SAMR model. This means that Samantha is using the smartboard affordances to create entirely new learning experiences, such as interactive activities that promote collaboration and real-time assessment, which are not possible without the technology. The combination of interactive puzzles and labelling exercises transforms the learning experience, showing a significant shift in pedagogical practice.

4.1.3 Narratives from the interview with teacher Zandaya.

Zandaya's prior lesson interview reveals a reliance on smartboard affordances; however, the use of the smartboard affordance is limited by inconsistent electricity access. When available, she primarily utilizes the annotation affordance within PowerPoint presentations, favouring this over the smart notebook's freehand writing capabilities. Her instructional approach emphasizes visual aids, such as diagrams, pictures, and videos, to enhance learner engagement and cater to diverse learning styles. She finds that the smartboard affordances significantly improve interactivity, allowing learners to visually connect with the content, particularly when illustrating complex processes like photosynthesis. This usage reflects the substitution level of the SAMR model, where technology acts as a direct substitute for traditional tools, in this case, using digital annotation instead of physical whiteboard markers. This demonstrates Zandaya's personal PCK, as she has developed a preference for specific tools and methods based on her own experiences and beliefs about teaching. Her pedagogical knowledge is evident in her choice to use visual aids and interactive elements to engage learners. Additionally, her content knowledge is demonstrated by her ability to select relevant visuals to explain complex biological processes.

Regarding common misconceptions, Zandaya identifies confusion between chlorophyll and chloroplast, as well as photosynthesis and cellular respiration. To address these, she employs the smartboard to display side-by-side visual comparisons, highlighting structural and functional differences. She believes this visual approach aids in clarifying distinctions and reinforcing correct concepts. This demonstrates augmentation within the SAMR model, where the smartboard enhances the learning experience by providing a way to present visual comparisons, potentially improving understanding beyond what traditional methods could achieve. This illustrates the development of her assessment knowledge, as she can identify and address common misconceptions. Her knowledge of the learners is also shown, as she understands the specific areas where her learners struggle. This aspect of her teaching could also be seen as developing collective PCK, as she is using teaching strategies that have been proven to be successful by other teachers in addressing these misconceptions.

To facilitate learner collaboration, she designs interactive worksheets with barcodes and displays questions on the smartboard for group work, aiming to promote active participation and peer learning. This indicates modification within the SAMR model. The technology allows for a significant change in the learning task, moving from individual worksheet completion to interactive group work facilitated by the smartboard. Her curricular knowledge is reflected in her design of activities that align with learning objectives and the learner's learning context is considered, as she adapts her teaching strategies to accommodate the available smartboard and the needs of her learners. In essence, Zandaya leverages the smartboard's visual affordances to clarify misconceptions, engage learners, and promote collaborative learning.

4.1.4 The importance of conducting the interview prior the collaborative lesson planning process.

Interviewing the three teachers individually before collaborative lesson planning is crucial for several reasons, primarily to understand their existing PCK and their current utilization of smartboard affordances within the SAMR model. These initial interviews reveal a spectrum of smartboard integration, from basic substitution to significant modification and even redefinition. For instance, Jade, despite technical limitations, predominantly operates within the substitution and augmentation levels, using smartboard affordances for visual presentations and dynamic annotations to clarify complex concepts. Samantha, on the other hand, demonstrates a progression towards modification and redefinition, employing smartboard affordances and PowerPoint to dynamically represent abstract concepts and create interactive, collaborative learning experiences like crossword puzzles and labelling exercises. Finally, Zandaya, facing infrastructural challenges, primarily uses smartboard affordances for substitution and augmentation, such as digital annotations and visual comparisons, but also incorporates elements of modification through interactive worksheets and group activities.

Understanding these individual approaches is vital for collaborative planning. It allows for the identification of strengths and weaknesses in each teacher's use of smartboard affordances. The interviews highlighted where each teacher pedagogically and technologically operate as viewed using the refined consensus model and the SAMR model as lenses.

As can be seen in the three narratives above, Jade primarily uses the smartboard affordances to replace traditional methods and others leverage the affordances to transform learning experiences. In addition, these first interviews revealed the teachers' personal PCK. This baseline understanding allowed for targeted discussions during the collaborative planning phase, where teachers could share strategies, address technical constraints, and explore innovative ways to utilize smartboard affordances to move towards higher levels of the SAMR model. See some of the teaching methods used by Jade in the extract below, when she was asked how she uses smartboard affordances to facilitate learner collaboration when teaching photosynthesis.

> **Jade:** I often use quizzes. You know this game gamified. I don't know what are called. There's a simulation software that I often use. There are quizzes from, for example, Kahoot. I use polls there and there, but I hardly use polls to force that discussion amongst the learners. So, the learners are then able to use the smartboard to brainstorm and also visualize their ideas connected them. That's all.

Moreover, by revealing each teacher's specific challenges and misconceptions regarding content and the integration of smartboard affordances, the interviews provided a foundation for developing a collaborative lesson that addresses these issues and maximizes the potential of smartboard affordances for all learners. For example, Jade and Zandaya both noted that learners *"mistake the chlorophyll for the chloroplast"* and *"do not know the difference between"* them. Zandaya explicitly stated, *"There's often confusion about the role of chlorophyll and the functions of chloroplasts in photosynthesis."* Jade added that *"there's often confusion about the role of chlorophyll, as well as the function of chloroplast"*. This confusion stems from a lack of understanding of the hierarchical relationship between these two components: chlorophyll is the pigment contained within the chloroplast organelle. To address this, Jade and Zandaya both stated that they *"display side-by-side comparisons"* and *"visuals of chlorophyll, as well as visuals of the chloroplast."* They explain how the two *"differ"* by showing learners the *"difference in terms of structure and also function."*

Identifying learners' misconceptions is crucial for teachers engaged in collaborative lesson planning. This practice enables teachers to move beyond a general understanding of learner struggles and to instead target the precise points of confusion that hinder learning. When teachers identify these misconceptions, they can design lessons that proactively confront and correct them, rather than just delivering content and hoping for the best. This targeted approach ensures that instructional strategies are not only more effective but also more efficient, preventing the same errors from recurring and building a more solid foundation of knowledge.

Therefore, the deliberate identification of misconceptions transforms lesson planning from a reactive process of responding to errors after they happen to a proactive, strategic effort to prevent them from taking hold in the first place, leading to a deeper and more lasting understanding for learners.

Within the refined consensus model of PCK, the interviews shed light on personal PCK, collective PCK, and reported enacted PCK. Personal PCK is evident in each teacher's individual approach to integrating smartboard affordances, reflecting their unique beliefs and understanding of how technology can enhance teaching and learning. Jade's focus on visual presentations and annotations revealed her personal PCK centred on clarity and direct instruction. Samantha's use of interactive activities demonstrated her belief in active learning and learner engagement.

Despite facing significant infrastructural challenges, Zandaya is a resourceful and dedicated teacher committed to her learners' learning. She admits that she does not use the smartboard *"very frequently"* because of external factors, stating, *"at our school we struggle with electricity at the times."* This highlights a significant obstacle she and her colleagues face. This mirrors the experiences of teachers in a study by Mihai (2020) on interactive whiteboards in urban Gauteng classrooms, where one secondary and 27 primary school teachers reported problems with electricity interruptions. However, Zandaya remains dedicated, immediately adding, *"but if there is electricity, I make sure that I use smart smartboards."* This shows her resourcefulness and commitment to using available technology to enhance learning whenever possible.

Through integrating smartboard affordances, she overcomes the limitations of purely verbal instruction and provides a more effective and engaging learning environment, particularly for visual learners, as she states, *"it also helps learners who can learn differently, who can learn visually. Unlike me coming to class and just be verbal."* Her use of PowerPoint presentations with annotations, and the inclusion of "pictures," "diagrams," and even "videos" with sound, demonstrates her proactive approach to making the most of the available technology to enrich her teaching and address learners' misconceptions about photosynthesis. Collective PCK, while not fully formed at this stage, begins to emerge as the teachers share their strategies and challenges. Enacted PCK, the actual implementation of PCK in the classroom, is reflected in the teachers' descriptions of their teaching practices, highlighting how they currently use smartboard affordances to facilitate learning.

The interviews also revealed the teachers' professional knowledge bases, including pedagogical knowledge, assessment knowledge, content knowledge, knowledge of the learners, curricular knowledge, and learning context. Pedagogical knowledge was demonstrated in their use of various teaching strategies, such as visual presentations, annotations, interactive activities, and group work. Assessment knowledge was implied in their use of interactive exercises like crossword puzzles and labelling activities, which can serve as formative assessments. Content knowledge was evident in their ability to clarify complex concepts and represent abstract ideas. Knowledge of the learners was reflected in their efforts to create engaging and accessible learning experiences, considering the diverse needs of their learners. Curricular knowledge was shown in their alignment of smartboard affordances integration with the curriculum objectives. Finally, the learning context, including infrastructural challenges, significantly impacts their ability to integrate smartboard affordances, highlighting the importance of considering the specific learning environment in technology integration.

4.2 Results from the analysis of the collaborative lesson planning process.

After conducting the interview with the three participating teachers respectively, the researcher and the three participating teachers collaboratively designed two photosynthesis lessons for Grade 11 Life Sciences learners, ensuring consistent content and delivery across three schools. This collaborative planning falls under collective PCK of the refined consensus model of PCK. The collaborative planning highlighted the critical role of PCK in selecting appropriate smartboard affordances. To align with national standards, the teachers utilized the Curriculum and Assessment Policy Statement (CAPS), and the Annual Teaching Plan (ATP) as depicted in Figure 11 and Figure 12, which specified the required content and limitations, such as excluding detailed biochemical processes of light and dark phases. Figure 11 is a screenshot from a curriculum document, outlining the specific content to be taught about photosynthesis, including the process, raw materials, energy transfer, food formation, and the release of oxygen. This figure is important because it sets a clear and explicit standard for the required knowledge, guiding teachers on what to focus on and what level of detail (e.g., mentioning light and dark phases without biochemical specifics) is expected from learners. Figure 12 on the other hand is a screenshot of the ATP that specifies the required content for a lesson on photosynthesis, including the process, key components, and its overall importance. This figure is important because it provides a precise instructional guideline for teachers, defining the scope and depth of the topic to ensure they cover the essential learning objectives without going into unnecessary detail.

Due to time constraints, topics like the effects of environmental variables on photosynthesis and the role of adenosine triphosphate were omitted. However, the lessons covered essential concepts: Lesson 1 focused on the structure of leaves and chloroplasts, the definition, requirements, products, phases, and importance of photosynthesis. Lesson 2 aimed to develop investigative skills by teaching learners about experimental apparatus and demonstrating starch production during photosynthesis.

Content
Photosynthesis • process of photosynthesis using words and symbols: the intake of raw materials, trapping and storing of energy, formation of food in chloroplasts and its storage. The release of oxygen. Mention only of light and dark phases *(no biochemical details of light and dark phases are required);*

Figure 11: CAPS document displaying content that must be taught to the learners.

Process of photosynthesis using words and symbols: The intake of raw materials, trapping and storing of energy, formation of food in chloroplasts and its storage

The release of oxygen

Mention only of light and dark phase **(no biochemical detail of light and dark phases is required)**

Importance of photosynthesis: release of oxygen, uptake of carbon dioxide from atmosphere, food production (trapping energy)

Figure 12: ATP displaying content that must be taught to the learners.

4.2.1 Insights drawn from Collaborative Lesson Planning and Teacher Oversights

This collaborative lesson planning process between the researcher and the three participating teachers revealed several key insights regarding the importance of PCK and adherence to curriculum documents. However, it also highlighted areas where teachers overlooked critical aspects during lesson planning. The collaborative process underscored the critical role of PCK in determining the appropriate smartboard affordances for lesson delivery. Teachers recognized that understanding how to integrate smartboard affordances with specific content knowledge and pedagogical strategies was essential. This realization reflects the understanding that knowledge of smartboard affordances alone is insufficient; teachers must possess the knowledge to align technological resources with learning objectives and learners needs. The discussion between the teachers and the researcher highlighted that teachers need to have knowledge of the affordances of the smartboard to teach the content as well as pedagogical knowledge.

Content was not the only component that the teachers had to decide on. They had to decide on the knowledge of the learners, and assessment knowledge. The researcher and the three participating teachers considered learners prior knowledge from their everyday lives and from grade 8, 9, 10, and grade 11 term one. They took into consideration that learners are familiar with the requirements of photosynthesis which are carbon dioxide, water and sunlight from their everyday lives. Some might even remember these requirements from grade 8 when they were taught photosynthesis in natural sciences. They are familiar with green leaves because they are found everywhere and were taught about the internal structure of the leaf in grade 10 and they were also taught about cells in grade 9 natural sciences and 10 life sciences where they were taught about the structure of the chlorophyll, which is where photosynthesis takes place. Regarding this, the teachers, together with the researcher they decided that for lesson 1 they will make use of a picture to elicit learners' prior knowledge as depicted in Figure 13 which illustrate a picture of a smartboard displaying a split-screen picture of tress. This figure is important because it demonstrates the visual affordance of the smartboard. This is the picture that the researcher and the three participating teachers agreed to use to introduce photosynthesis by drawing from learners' prior knowledge through questioning.

Figure 13: A picture of trees that the researcher and the participating teachers agreed to use to elicit learners' prior knowledge.

The three participating teachers and the researcher also decided that they will recap content knowledge from grade 10 about the internal leaf structure and chloroplast because this is the knowledge they will need for further understanding of photosynthesis. This is also something that is required by the ATP as depicted in Figure 14. This figure illustrates a screenshot from the ATP that outlines the specific content to be revised, such as cell and leaf structures, from Grade 8 to 10 before a new lesson. This figure is important because it serves as a guide for teachers to activate and build upon learners' prior knowledge, ensuring they have the foundational understanding necessary to grasp new concepts.

ORIENTATION
Revise basic cell structure with focus on the chloroplast, leaf structure mitochondria and plant and animal tissues from grade 9 and grade 10 Revise basic photosynthesis and respiration from grade 8

Figure 14: ATP displaying prior knowledge from previous grades.

4.2.2 Pedagogical approaches that the researcher and the three participating teachers agreed upon during the collaborative lesson planning process.

For lesson 1, the researcher and the three participating teachers decided to use the same picture on smartboard, not to only elicit learners' prior knowledge but to also draw learners' attention. They also collectively decided that they were going to use other visual aids like diagrams and videos to appeal to visual learners and auditory learners. They also decided that they were going to do concept reinforcement where they will be repeating key concepts such as photosynthesis definition, requirements for photosynthesis to take place to solidify learners understanding. Furthermore, real world connection such as using a picture of green plants in a garden was one of the teaching methods that they agreed on as depicted in Figure 15. This figure displays a picture of green plants in a garden bed. This image was chosen by the researcher and the three participating teachers to serve as a tangible, real-world example for learners. Its purpose was to connect the abstract scientific concept of photosynthesis to their own experiences, making the topic more relatable and easier to understand.

Figure 15: A picture of green plants, selected by the researcher and the three participating teachers to connect the lesson to real-world experiences for the learners.

Vocabulary reinforcement is another form of teaching practice that the researcher and the three participating teachers decided to use to ensure that the learners understand how to properly write about photosynthesis and to also be in a position where they can answer the exam questions. They also agreed on using a quiz to test learners understanding of photosynthesis as depicted in Figure 16.

Figure 16: A QR Code which, when scanned, leads to a multiple-choice topic test on photosynthesis. This test was designed collaboratively by the researcher and the three participating teachers and was scheduled for learners at the end of the first lesson.

For lesson 2, the researcher and the three participating teachers agreed on using images of different materials as one of the teaching practices to draw learners' attention and to ensure that the learners retain knowledge about photosynthesis well as depicted in Figure 17. This figure displays six pieces of scientific equipment and chemical reagents commonly used in a laboratory setting, including a bottle of iodine solution, droppers, a Bunsen burner, forceps, a test tube, and tongs. It is important because it visually represents the essential tools required to conduct an experiment, such as the starch test for photosynthesis.

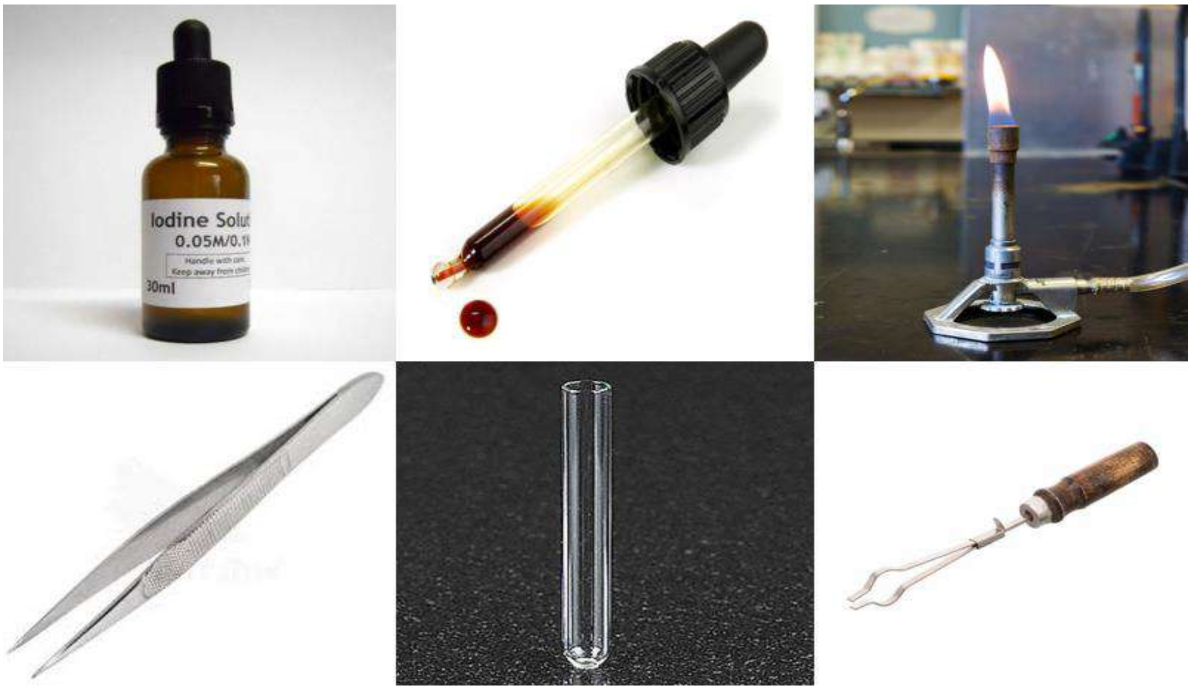

Figure 17: Pictures that were agreed upon by the researcher and the three participating teachers to show the learners the equipment needed to conduct the starch test.

In addition to this, they also decided to use video to engage the learners while breaking down the complex process of photosynthesis given that it occurs at a microscopic level as depicted in the link below.

https://youtu.be/zWO-bTi6u8M?si=4D391TyZ-a8XIZ6x

Another pedagogical practices that they agreed on was displaying a diagram and review the key concepts in the test for starch test experiment, such as the role of chlorophyll. They also decided to give learners an informal task to assess their understanding on how to do a test for starch experiment as depicted in Appendix 14. Furthermore, they also agreed to give learners a 30 second game to emphasise key concepts like chlorophyll while making learning to be fun.

4.2.3 Smartboard affordances that the researcher and the participating teachers agreed upon during the collaborative lesson planning process.

The content knowledge, curricular knowledge, knowledge of the learners, pedagogical approaches and assessment knowledge that the researcher and the three participating teachers had to agree on played a huge role is deciding to use the following smartboard affordances which falls under pedagogical knowledge:

- Writing and Highlighting on the smartboard.
- Touch sensitivity.
- Animation video.
- Saving work.
- IQ Interactive Education Platform.
- Digital Document Presentation.
- Interactive Learning Activities.
- Internet connectivity.
- Timer.
- Stylus.

In a study by Abdullah et al. (2020) titled "Does the Use of Smart Board Increase Students' Higher Order Thinking Skills (HOTS)?," researchers investigated how certain smartboard affordances in a mathematics classroom helped learners learn. The study focused on how these affordances influenced learners' ability to think critically and solve complex problems. However, the current study did not look at how learners critically think. Instead, it focused on how teachers use the affordances of a smartboard to teach about photosynthesis. It specifically investigated the ways a teacher can use the smartboard affordances to explain the topic.

4.2.4 Oversights and Missed Opportunities drawn from Collaborative Lesson Planning.

Despite the collaborative effort and adherence to curriculum documents, oversights occurred during lesson planning process. The time constraints, while acknowledged, led to the exclusion of important related topics, such as the effects of environmental variables on photosynthesis and the role of adenosine triphosphate. While these omissions were justified within the given time frame, they might limit learners' understanding of photosynthesis. The researcher and the three participating teachers overlooked the importance of integrating these topics, not even briefly, to provide a more complete view. The reliance on curriculum documents, while necessary, led to a rigid approach to lesson planning. The researcher and the three participating teachers overlooked the importance of flexibility and responsiveness to learners' needs and interests.

Adapting lessons based on learners' questions, misconceptions, or prior knowledge can enhance engagement and promote deeper learning. The researcher and the three participating teachers also overlooked the importance of integrating formative assessment throughout the lesson to track learners' understanding and adjust instruction accordingly. Furthermore, while the collaborative lesson planning focused on content delivery and practical skills, it was crucial to consider the development of higher-order thinking skills. The researcher and the three participating teachers overlooked opportunities to incorporate activities that promote critical thinking, problem-solving, and application of knowledge to real-world scenarios. For example, while the practical investigation of starch production is valuable, linking it to broader ecological implications could enhance learners' engagement and understanding.

4.2.5 The importance of collaborative lesson planning.

Collaborative lesson planning is significant since it gave the researcher and the three participating teachers a valuable platform for knowledge exchange and development of shared pedagogical content knowledge (collective PCK), which was deemed crucial for selecting appropriate smartboard affordances. The meetings that the researcher and the three participating teachers had during the lesson planning process have fostered a collective understanding of how to leverage smartboard affordances given that the teachers have diverse experiences and expertise on the use of the smartboard affordances. The teachers were able to share their pedagogical strategies such as using multimedia from the smartboard ensuring that the technology is used to enhance learning outcomes rather than simply replace traditional teaching methods.

This shared learning environment allowed for the development of a common pedagogical language around the integration of smartboard affordances, promoting consistency and best practices across the three classrooms. Furthermore, the collaborative lesson planning sessions ensured that the lessons adhered to the CAPS and the ATP. These documents served as guides for content selection and scope, guaranteeing that national standards were met while utilizing smartboard affordances. The researcher and the three participating teachers also considered knowledge of the learners, planning to elicit prior knowledge through everyday examples and reviews of previous grades, using visuals and recaps displayed on the smartboard. This approach aimed to bridge the gap between existing understanding and new concepts related to photosynthesis. Furthermore, the collaborative lesson planning allowed us to see that learners in our three different contexts have same misconceptions and that the concepts that are challenges for them to learn are also the same. This knowledge motivated us to brainstorm and come up with approaches that we collectively thought will resolve these issues.

Furthermore, collaborative lesson planning gave the researcher and the three participating teachers an opportunity to explore the potential of smartboard affordances in a supportive and interactive setting. The researcher and the three participating teachers were able to brainstorm creative ways to integrate the smartboard affordances by discussing specific learning objectives and curriculum requirements. This process encouraged experimentation and reflection, leading to the discovery of certain approaches to teaching. Teachers worked together to develop an interactive learning tool using PowerPoint. They built a presentation filled with visuals, including pictures, diagrams, and animated videos, to enhance learner engagement. In addition, they designed a fast-paced, 30-second game within the PowerPoint presentation to reinforce the definitions of important biological terms like photolysis and adenosine triphosphate. This game aimed to strengthen learners understanding through a fun and competitive format. This collective effort not only improved individual teacher proficiency but also their confidence in using smartboard affordances.

Essentially, the selection of smartboard affordances was completed, including writing and highlighting tools, touch sensitivity, animation videos, saving work, the IQ Interactive Platform, digital documents, internet access, and a timer. These tools facilitated dynamic and interactive lessons, enhancing learner engagement and understanding of photosynthesis. The ability to save work and use digital documents allowed for easy access and review of materials.

4.3.1 Insights drawn from the narratives derived from a video recording of the first lesson from school 1

Jade initiated the lesson by reviewing the concept of photosynthesis, utilizing a smartboard to display diagrams of leaves and chloroplasts. This visual aid allowed learners to engage with the material and share their initial thoughts, such as the presence of green pigment, competition for sunlight, and the exchange of gases. The smartboard facilitated the presentation of biological terms like photosynthesis, photolysis, chlorophyll, chloroplast, phosphorylation, ATP, glucose, and NADP, with Jade writing definitions directly on the board, enhancing visual learning as depicted in Figure 18. This figure shows a teacher using a smartboard to write and annotate a list of biological terms, such as photosynthesis and chlorophyll. It is important because it demonstrates the interactive nature of the smartboard as a teaching tool, allowing for real-time annotation and visual clarification of complex concepts during a lesson. This use of the smartboard to display diagrams and write definitions directly on the smartboard represented the substitution level of the SAMR model, as it replaced traditional whiteboard use with digital display.

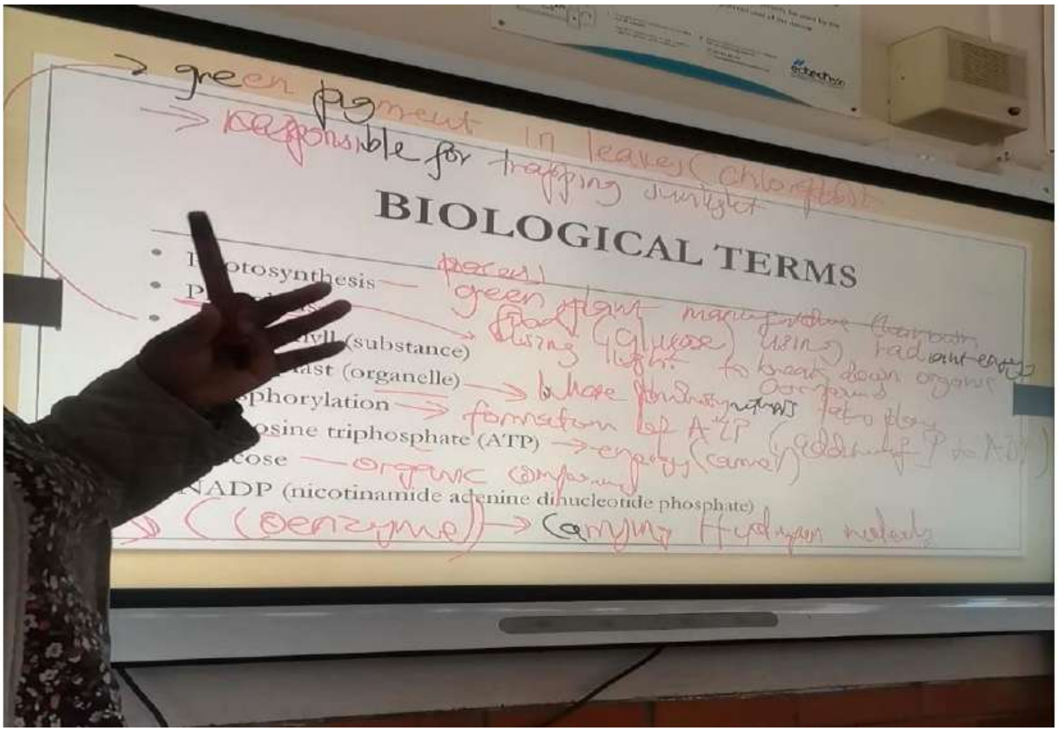

Figure 18: Biological terms that Jade was teaching the learners through annotation.

Furthermore, the smartboard also displayed the chemical formulas for water (H_2O) and carbon dioxide (CO_2), reinforcing the chemical aspect of photosynthesis. Jade then transitioned to the requirements of photosynthesis, displaying images of water, sunlight, and carbon dioxide. The carbon dioxide was displayed using a molecular formula as depicted in Figure 19. This figure is important because it visually simplifies the core components of a biological process, making it easier for learners to understand and recall the necessary inputs for photosynthesis. The smartboard affordance displayed here is digital document presentation, which allows teachers to show and manage visual aids like a PowerPoint presentation.

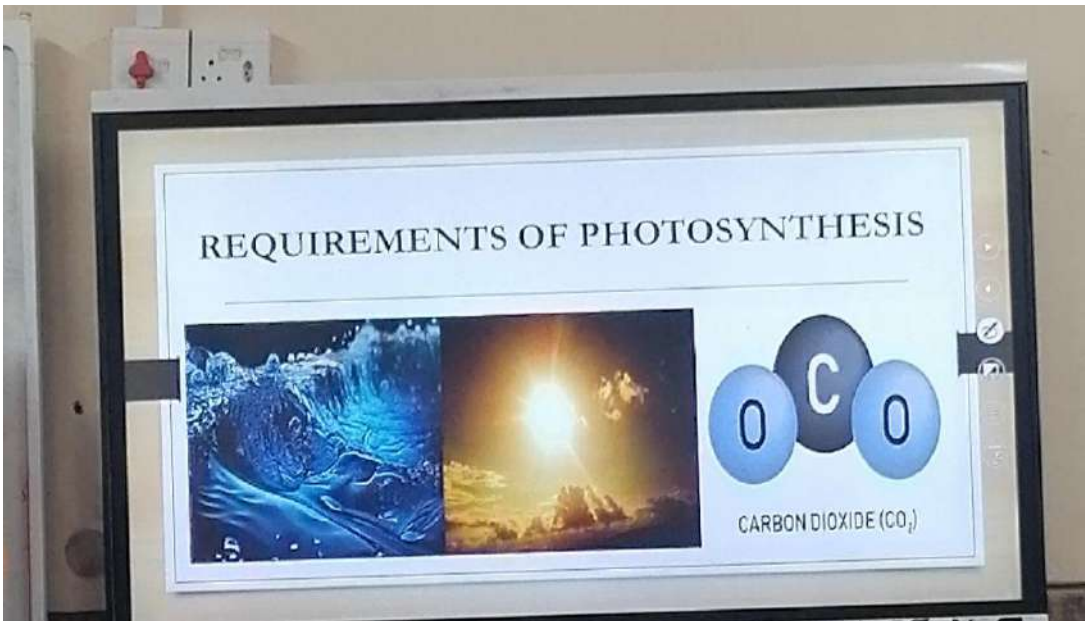

Figure 19: Pictures displaying the requirements of photosynthesis.

Through interactive questioning, Jade guided learners to identify these requirements, emphasizing the role of chlorophyll, which was also discussed in conjunction with the structure of the leaf presented on the smartboard. Jade asked a series of open-ended questions to facilitate a learner-centered lesson. She started with a broad question: *"What do you think are the requirements of photosynthesis? ...From these pictures that I have right on the board."* This prompted learners to think critically and draw conclusions from the visual aids. The extract below depicts responses from two learners, among others.

Learner 13: *"Water"*; This response is directly linked to one of the visual clues. Jade acknowledges the response and connects it to the diagram *"she's seeing water right there"*. This validates the learner's contribution and encourages further participation.

Learner 14: *"Sunlight and Carbon dioxide"* ; After the initial response, Jade uses follow-up questions *"Sunlight as well as, what is the last one?"* to scaffold the learners' thinking and prompt them to identify the remaining requirements. This structured questioning ensures that all key elements are covered.

The smartboard was used to improve teaching, not to replace Jade. It helped learners understand the complex topic of photosynthesis by displaying detailed diagrams of leaf anatomy and chloroplast. This allowed learners to see the specific places where the process happens. The smartboard also showed chemical formulas and allowed for interactive questions, which improved upon traditional teaching methods. This approach is at the augmentation level of the SAMR model, which means the technology enhances what is already being done. Unlike the findings of Mokoena et al. (2022), where smartboards were only used as projectors, this research shows a more advanced use of the smartboard affordances as a teaching tool. Instead of taking over the lesson, the smartboard was a valuable aid that helped the teacher explain an abstract topic.

Furthermore, Jade used the smartboard to illustrate the two phases of photosynthesis: the light-dependent phase in the grana and the light-independent phase in the stroma. Jade used diagrams and annotations on the smartboard to explain the processes of photolysis, adenosine triphosphate formation, and the combination of hydrogen and carbon dioxide to form glucose, enhancing the clarity of these complex processes. This use of the smartboard to illustrate complex processes with diagrams and annotations, providing understandable explanation, represents the modification level of the SAMR model, as it significantly redesigned the teaching process.

Finally, Jade presented the chemical equation for photosynthesis on the smartboard, visually connecting the reactants (carbon dioxide and water) with the products (glucose and oxygen). A summary diagram was displayed, showcasing the flow of substances and energy through the leaf, chloroplast, grana, and stroma. The smartboard's interactive capabilities allowed the teacher to annotate and highlight key points, reinforcing the learning objectives and providing an overview of the photosynthesis process. Jade also used the smartboard to show a micrograph of a chloroplast, to show real world examples. This interactive use of the smartboard to connect chemical equations, display summary diagrams, annotate key points, and show real-world micrographs, creating a new and engaging learning environment, represents the redefinition level of the SAMR model.

Jade's personal PCK was manifested in her strategic use of visual aids, such as diagrams, and interactive questioning, showcasing her unique ability to simplify complex biological processes for her learners. This personal PCK was grounded in her strong content knowledge, evident in her accurate presentation of biological terms, chemical formulas, and the steps of photosynthesis. Simultaneously, in the lesson, collective PCK was demonstrated through her adherence to established scientific terminology and chemical formulas, aligning her instruction with what was agreed on with other two participating teachers and the researcher during the planning process. The enacted PCK was observed in her real-time adjustments and annotations on the smartboard, reflecting her responsiveness to learner engagement and her ability to facilitate understanding during the lesson. Furthermore, the enacted PCK was also observed in real-time when she randomly asked a learner to come and do corrections on the smartboard through writing and annotation as depicted in Figure 20. This figure is important because it shows the use of smartboard affordances, allowing for real-time problem-solving and annotation to guide learners through a visual activity. The smartboard affordance shown here is writing and annotating with a stylus, which enables the teacher or learner to add handwritten notes, labels, and corrections directly onto the projected content.

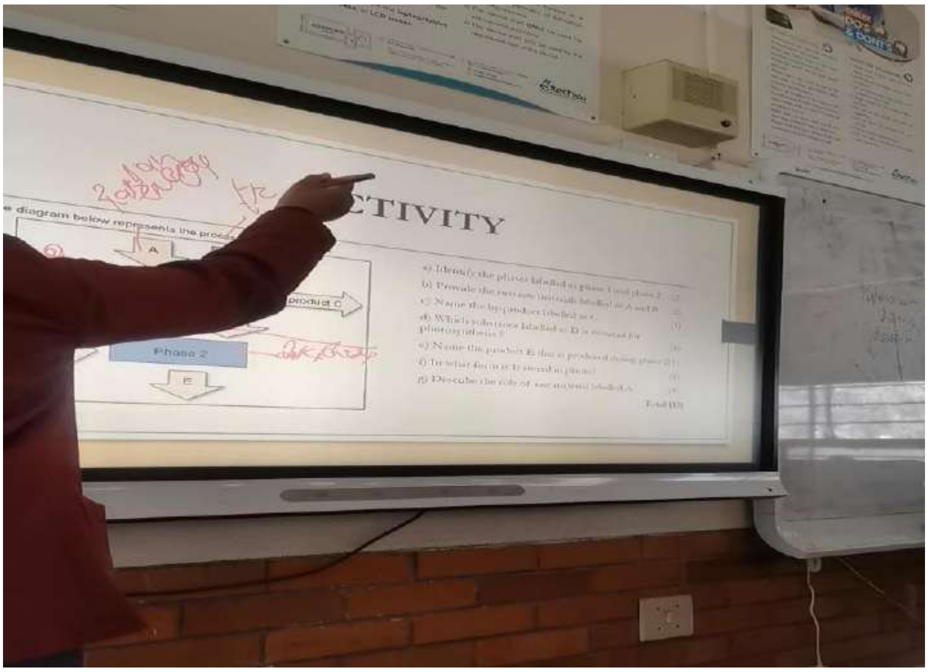

Figure 20: Learner doing corrections on the smartboard through writing and annotation.

This dynamic enactment was supported by her pedagogical knowledge, as she employed visual aids and step-by-step explanations, and her knowledge about the learners, enabled her to tailor explanations to their comprehension level and engaged them with relevant visuals. Furthermore, her assessment knowledge, was crucial as she checked learner understanding through their initial thoughts and responses. Moreover, her curricular knowledge was demonstrated by her adherence to the scientific concepts related to photosynthesis. In essence, Jade's lesson integrated her personal, collective, and enacted PCK with her content, pedagogical, assessment, learner, and curricular knowledge, creating a complete learning environment.

4.3.2 Insights drawn from the narratives derived from a video recording of the first lesson from school 2

Samantha began by displaying a picture of trees to elicit learners' initial thoughts about plants and trees as depicted in Appendix 10. This is a substitution level of SAMR Model. This strategy leveraged the smartboard's ability to display images and videos, sparking curiosity and activating prior knowledge. Throughout the lesson, Samantha frequently checked for understanding by asking questions and encouraging learners to share their thoughts. Furthermore, the smartboard affordances were used to enhance understanding by displaying diagrams of the chloroplast, chemical equations, and visual representations of the light and dark phases (Substitution level of SAMR Model). Annotations and highlighting tools were also used to emphasize key components and processes as depicted in Figure 21. This figure shows an image of a teacher who is directly annotating a smartboard. The smartboard affordance shown is writing and annotating with a stylus, which enables the teacher to add handwritten text and labels directly onto the smartboard. This demonstrates substitution in the SAMR model, as the smartboard replaced traditional methods of displaying images and diagrams.

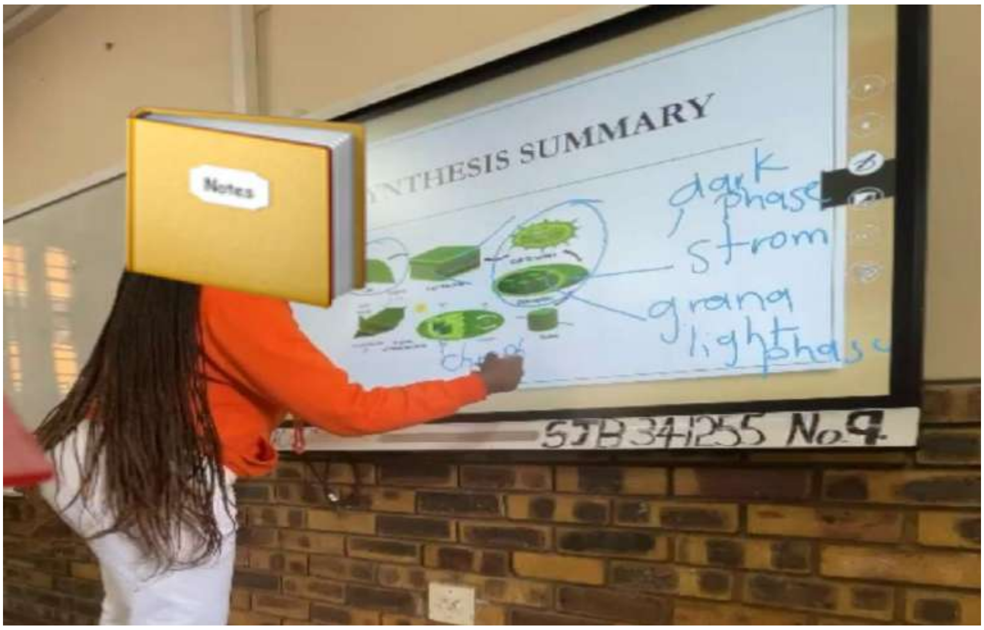

Figure 21: Samantha annotating on the smartboard.

Interactive elements, such as drag-and-drop activities or labelling exercises, were used to further engage learners and reinforce their understanding (Substitution level of SAMR Model). The teacher also used a video to enhance the understanding of the process (augmentation level of SAMR Model). This demonstrated Samantha's pedagogical knowledge by selecting appropriate teaching strategies and resources. The use of visuals and interactive elements reflected her assessment knowledge in determining learner understanding. Her ability to explain complex scientific concepts like photosynthesis and chloroplast structure highlighted her strong content knowledge. She demonstrated her knowledge of the learners by eliciting initial thoughts and frequently checking for understanding. The structuring of the lesson with visual aids and interactive activities also revealed her curricular knowledge in aligning with educational objectives. This use of interactive elements and videos represented augmentation within the SAMR model, as the smartboard enhanced the learning experience beyond what traditional methods could offer.

Furthermore, Samantha encouraged active participation through questioning, discussion, and explanations led by learners. The smartboard affordances were used to create collaborative learning activities. For example, Samantha awarded the learners an opportunity to draw a diagram of a chloroplast on a smartboard (augmentation level of SAMR Model). Furthermore, the lesson concluded with a review of the key concepts and an activity to assess learners' understanding. The smartboard was used to display the activity questions and feedback (Substitution level of SAMR Model). In addition to this, Samantha's ability to stick to the selected teaching strategies that engaged learners and fostered understanding during the lesson exemplified her enacted PCK.

4.3.3 Insights drawn from the narratives derived from a video recording of the first lesson from school 3

This transcript showed Zandaya guiding learners through the complexities of photosynthesis, using a smartboard as a central pedagogical tool. The lesson began with an observation activity, prompting learners to describe what they saw in a picture to activate prior knowledge and transition into the day's topic. Zandaya's questioning technique, which elicited learner responses, demonstrated strong pedagogical content knowledge and an understanding of her learners. Zandaya attempted to use the smartboard to illustrate the structure of the chloroplast and the light-dependent reactions as depicted in Figure 22. However, she struggled with the smartboard's touch sensitivity affordance, a technical issue that prevented her from using these visual aids well. This is similar to a challenge noted in a study by Uqba et al. (2024), where slow or delayed handwriting on smartboards hindered effective use. These technical problems frustrated the teacher and the learners, interrupting the lesson's flow. This is an example of the substitution level of the SAMR Model, where the smartboard functioned as a direct substitute for a traditional whiteboard without adding significant functional change.

The extract below shows how Samantha used the smartboard to display structure of the chloroplast and why.

> *"So, this one yile (is) that you see in our textbooks normally but then in the exams they normally show this one."* Samantha is referring to two different visual representations of a chloroplast. The *"this one"* likely refers to an image she is pointing to or displaying, which she then contrasts with the *"one"* that learners see in exams. This suggests she is using a digital display to show these images.
>
> *"Then when you guys see the picture niyaxakeka (you're confused) and you guys say yini manje le (what is this?)."* Samantha's statement implies that she is anticipating learner confusion with the second image, the micrograph. She is using the smartboard to proactively address a common point of difficulty for her learners by having both images readily available to show and compare.
>
> *"So, this is a microscopic picture of a chloroplast. It is known as ama micrographs."* Samantha explicitly identifies the second image as a *"microscopic picture,"* or *"micrograph."* The ability to project high-quality images like micrographs, which are often used in scientific contexts, is a core affordance of smartboard technology.

Despite these technological challenges, Zandaya's pedagogical approach she was a dedicated teacher who was able to combine questioning, explanation, and a recall of prior knowledge. She frequently asked learners to define terms and explain processes, encouraging active participation. She also connected the current lesson to previous learning, such as grade 8 plant biology and grade 10 biodiversity, demonstrating an understanding of curriculum progression. While her content knowledge was evident, she occasionally made minor errors, such as confusing mitochondria with chloroplasts, which she quickly corrected, showcasing her enacted pedagogical content knowledge (PCK). The teacher, Zandaya, incorrectly stated that the "entire process" takes place in the grana as depicted in the extract below. The grana are stacks of thylakoids within the chloroplast where the light-dependent reactions of photosynthesis occur. The light-independent reactions, however, take place in the stroma, which is the fluid-filled space surrounding the grana inside the chloroplast. Therefore, the entire process of photosynthesis does not occur solely in the grana.

Zandaya: Two hydrogen and oxygen! H_2O. So, what will happen here, remember ukuthi *(that)* this entire process takes place in the? In the?

Learners: Chloroplast

Zandaya: Takes place in the grana. This entire process esizobe siyi explaina la *(the process that we will be explaining)* it takes place in the?

Learners: In the grana

Zandaya: In the grana and the grana is found in the chloroplast. So, this entire process the site is the chloroplast. OK, so basic what will happen here as you can see now this grana, there's a chlorophyll angisho (right). It will absorb the radiant energy and then even water will be reabsorbed angisho amanzi ayangena la *(the water enters here)*.

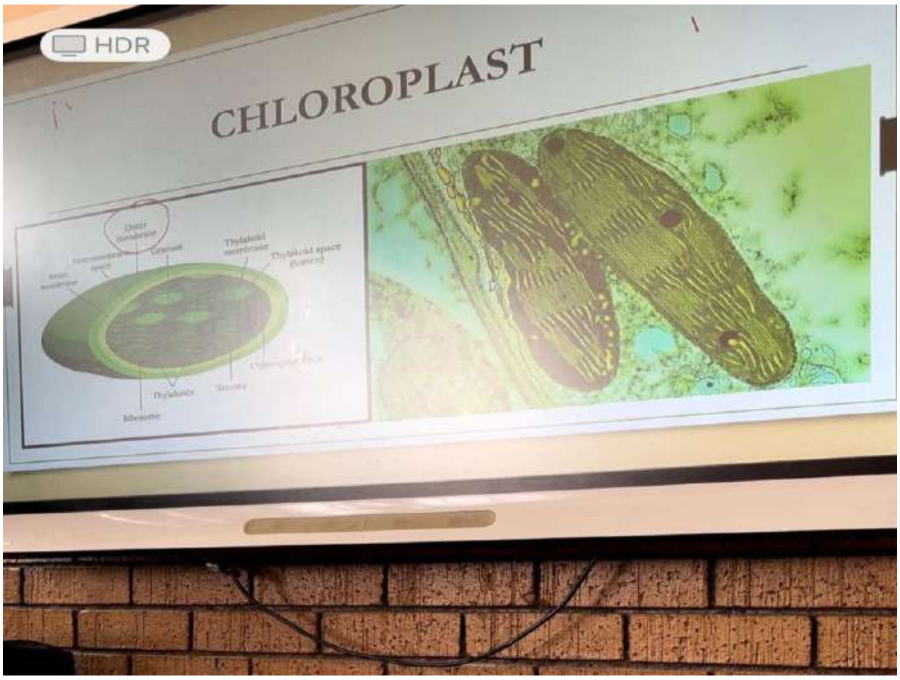

Figure 22: An example of visual aids used by Zandaya to show the learners a structure of a chloroplast.

Figure 22 shows an image of a smartboard displaying a slide with two detailed diagrams of a chloroplast, showing both a simplified cross-section with labels and a more realistic electron microscope image. These detailed diagrams were used to provide a visual representation of a complex biological structure, helping learners understand the different components of the chloroplast and its appearance.

Furthermore, Zandaya also struggled to maintain a clear distinction between the roles of chlorophyll and chloroplasts. This error highlights a potential weakness in her content knowledge, specifically in the differentiation of cellular structures. Zandaya’s curricular knowledge was shown by linking the topics to the prior grades and her assessment knowledge was shown by her questioning and eliciting responses from learners.

Despite the technical difficulties faced by Zandaya, the interaction between her and the learners was generally positive, with learners actively participating in the discussion. The learners' responses indicated varying levels of understanding, and the teacher attempted to address their misconceptions. The frequent use of code-switching, alternating between English and isiZulu, is a notable aspect of the teacher's communication style, likely reflecting the linguistic context of the classroom (knowledge of learners). This code-switching demonstrated Zandaya's knowledge of the learners and the learning context, adapting her language to better facilitate understanding. Given that the use of code switching was something not discussed with the other teachers during the planning process, then it can be another instance of the teachers enacted PCK. Additionally, the collective PCK, or the shared understanding of teaching practices among teachers, could potentially have helped Zandaya navigate the technical difficulties and refine her explanations.

4.3.4 Refined consensus model of PCK and SAMR as lenses: Analysing Smartboard Implementation and Progression in Three School Settings.

It was crucial for the three participating teachers to proceed with teaching the planned lessons, rather than stopping at the planning stage, because the implementation phase is where the theoretical framework translates into practical learning experiences. The collaborative planning provided a structured approach, but the actual teaching allowed for real-time adjustments and interactions that are essential for pedagogy. In each school, the teachers leveraged collective PCK, which is a component of refined consensus model of PCK, and the smartboard affordances to enhance their lessons, demonstrating the importance of moving beyond planning to actual application.

In School 1, Jade used the smartboard affordances to substitution level by simply displaying diagrams and chemical formulas, replacing traditional chalkboards. However, they also moved towards augmentation by annotating diagrams, highlighting key points, and presenting micrographs, which enhanced visual learning and provided a more dynamic presentation than a static image. Jade's use of the smartboard to show the flow of substances and energy, and to connect reactants and products in the chemical equation, augmented the learning experience by providing clarity. This demonstrated Jade’s enacted PCK. Jade’s ability to use the smartboard affordances in this manner drew upon the three participating teachers and the researcher’s pedagogical knowledge, content knowledge, and knowledge of the learners.

Drawing upon the findings of Dudaitė and Prakapas (2019) and the classroom practices observed in School 2, it is evident that smartboard affordances significantly enhance learner engagement and motivation. The study by Dudaitė and Prakapas found that learners were highly motivated to participate in activities, willingly approaching the smartboard to complete tasks. Similarly, in School 2, Samantha’s use of the smartboard affordances exemplified a progression to the modification level of the SAMR model. Samantha modified the learning experience, making it more engaging and participatory by using the smartboard affordances for interactive elements, such as drag-and-drop activities and labelling exercises. Allowing learners to draw diagrams on the smartboard also moved towards modification, providing a collaborative learning environment as depicted in Figure 23. This figure shows a learner drawing a simple diagram of a chloroplast on a smartboard and labelling its parts like lamella and starch grain. It is important because it demonstrates how a smartboard can allow real-time creation and labelling of diagrams to facilitate learning and engagement. The smartboard affordance used here is writing and drawing, which allows the learner to draw diagrams directly on the smartboard.

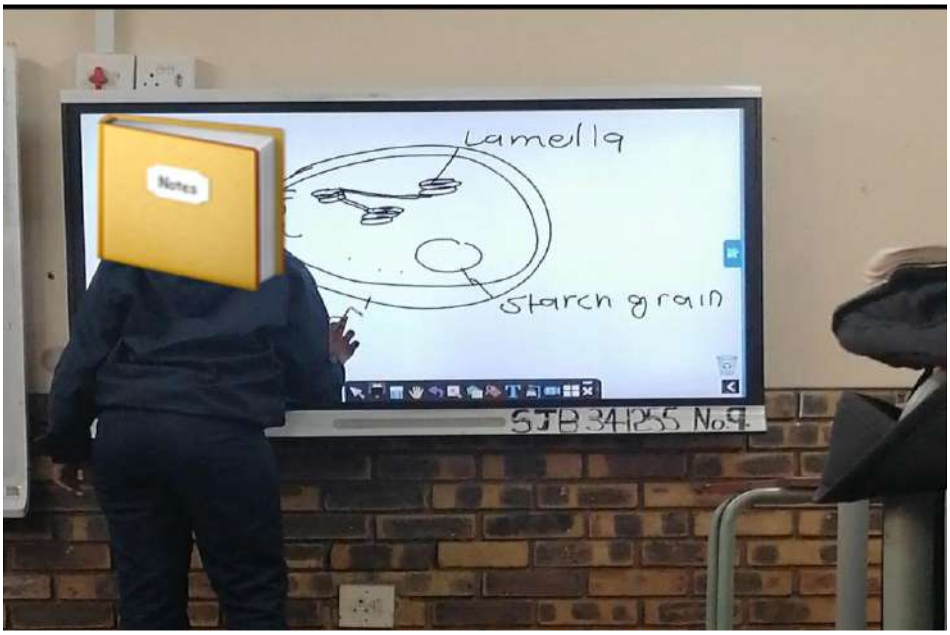

Figure 23: A learner drawing a diagram of a chloroplast and labelling it with the help of her classmates.

The use of videos, interactive questioning, and learner-led explanations further emphasized the interactive smartboard affordances, allowing for a more dynamic and engaging lesson than could have been achieved with traditional methods. This showed Samantha's enacted PCK, influenced by her personal PCK and the teachers 'collective PCK. Additionally, Samantha's lesson displayed strong assessment knowledge and curricular knowledge, as well as pedagogical knowledge.

In School 3, Zandaya's attempt to use the smartboard affordances was hindered by technical difficulties. Despite this, the intention was clear: to use the smartboard for augmentation by displaying diagrams and visual aids to enhance understanding of complex processes. Zandaya's effort to use the smartboard to illustrate chloroplast structure and light-dependent reactions, even with technical issues, shows the intention to move beyond simple substitution. The technical difficulties highlighted the importance of testing and preparation but also underscored the potential of smartboard affordances to enhance lessons when properly utilized. This demonstrated that even with technical difficulties, Zandaya's personal PCK and intended enacted PCK were present. The technical difficulties indicated that Zandaya's knowledge of the learning context, specifically concerning smartboard readiness, could have been improved.

Ultimately, teaching the lesson allowed the teachers to assess the effectiveness of their planned activities, to identify areas for improvement, and to gain valuable insights into learner understanding. The practical application of the lesson plans, utilizing the smartboard affordances, provided tangible learning experiences that could not have been achieved through planning alone. Although enacted PCK of each teacher showed the influences of collective PCK, there were nuances in each teacher's enacted PCK influenced by other factors such as the learning context and teacher's knowledge of the various domains, which included pedagogical knowledge, assessment knowledge, content knowledge, knowledge of the learners, and curricular knowledge.

The pedagogical reasoning demonstrated by the teachers highlighted the critical transition from theoretical planning to practical implementation. Jade, Samantha, and Zandaya each showcased their enacted PCK, revealing how their personal and collective pedagogical knowledge, content knowledge, and knowledge of learners translated into classroom practice. Jade's approach, while starting at the substitution level with the smartboard, progressed to augmentation through annotations and dynamic visualizations, demonstrating a clear understanding of how to enhance visual learning. Samantha, in School 2, moved towards modification within the SAMR model, leveraging interactive elements like drag-and-drop activities and collaborative drawing to foster a more engaging and participatory learning environment. Her lesson revealed strong assessment and curricular knowledge, alongside her pedagogical skills.

Zandaya's experience, though hampered by technical difficulties, still illuminated her intent to enhance learning through visual aids, particularly in illustrating complex processes. Despite the setback, her effort showcased her personal PCK and intended enacted PCK. However, the technical issues underscored the importance of context-specific knowledge, particularly regarding the readiness of technological tools. Ultimately, the act of teaching allowed each teacher to assess the planned activities, identify areas for improvement, and gain valuable insights into learner understanding. The distinctions in each teacher's enacted PCK, influenced by their unique strengths and weaknesses in areas like assessment, content, and learner knowledge, became apparent through the practical application of their lesson plans. The teachers' experiences illustrated that while collaborative planning provided a solid foundation, the true realization of pedagogy occurred during the interactive and adaptive process of teaching.

4.4.1 Insights drawn from the narratives derived from listening to audio recordings from interview conducted after the first lesson was taught at school 1.

Based on the interview session depicted in Appendix 16, Jade highlighted several key points regarding the use of the smartboard in teaching photosynthesis. She found that utilizing the smartboard's presentation affordances, along with displaying (substitution level of SAMR Model) and annotating diagrams of the chloroplast (augmentation level of SAMR Model), significantly aided learner understanding. Jade's pedagogical reasoning here demonstrates PCK, specifically in the professional knowledge base of pedagogical knowledge. She recognized the value of visual aids and annotation in clarifying complex biological processes. Furthermore, Jade found that integrating educational games, such as a 30-second quiz and Google Forms, enhanced learner engagement. This illustrates the augmentation and modification levels of the SAMR model, where the smartboard improved and transformed the learning experience. Again, this is rooted in PCK within the pedagogical knowledge professional knowledge base. She understood the impact of interactive activities on learner learning.

Jade also discussed the challenges of providing immediate feedback due to limited internet connectivity and learner access to technology. She mentions, *"I do not have internet connectivity. My learners do not have cell phones or gadgets that they can use,"* which directly addresses the core issues. Jade explains that if she did have these resources, she would use tools like Kahoot!, virtual field trips, and interactive whiteboard apps to provide immediate feedback. However, due to the *"constraint of internet activity, as well as...the fact that we are marginalized in terms of...having technology,"* she cannot use these methods. This evidence highlights that while she is aware of smartboard affordances for immediate feedback, her ability to implement them is severely limited by a lack of infrastructure and learner-owned devices.

This reflects assessment knowledge within professional knowledge bases of PCK, as she understands the importance of feedback but faces logistical barriers. Her pedagogical reasoning shows an awareness of the ideal scenario but also a realistic adaptation to her circumstances. Finally, Jade observed that most learners were actively engaged, with disengagement primarily attributed to individual personalities and learning styles. She noted that quiet learners or those with kinaesthetic learning preferences might not fully participate in interactive activities. This highlights her awareness of diverse learner needs and the importance of differentiated instruction, reflecting pedagogical knowledge within the professional knowledge bases of PCK. Her reasoning shows she understands the limitations of certain teaching strategies for learners, and that engagement is also impacted by personality, and learning style.

4.4.2 Insights drawn from the narratives derived from listening to audio recordings from interview conducted after the first lesson was taught at school 2.

From the interview session as depicted in Appendix 19, Samantha highlighted several key points regarding the use of the smartboard in facilitating learners' understanding of photosynthesis. She found the annotation feature of the smartboard particularly beneficial, as it allowed her to visually enhance the PowerPoint presentation, making abstract concepts more accessible to learners. This aligns with the SAMR model's augmentation level, where technology enhances traditional teaching methods. Furthermore, according to the interview audio recording, Samantha employed a "show and tell" strategy, using pictures of trees to engage learners and connect the topic to real-life applications as depicted in the extract below.

> "So, in the beginning of the lesson, I started with a show and tell where I showed the learners a picture of trees and then they had to describe what they are seeing there and in which concept are they linking that picture to in life sciences. So, this makes them to be able to gain interest into the topic and to bring their concentration into what they are going to learn about on the day."

This demonstrates her PCK as she understands how to make the content relatable and stimulate interest. The immediate feedback provided by the smartboard's quiz function was also identified as a significant advantage. Samantha suggested using the smartboard to display past question papers and memos, further emphasizing its potential for assessment and providing learners with direct feedback on their understanding, showcasing her assessment knowledge within the PCK framework.

Samantha recognized that many learners are visual, and the smartboard's ability to display organelles enhanced their comprehension. This highlights her understanding of learners' diverse needs and preferences, a crucial aspect of PCK. However, she encountered challenges with annotating due to her long nails, prompting her to devise alternative solutions, such as using a smartboard pen or a pencil with a rubber eraser. This demonstrates her adaptability and problem-solving skills in integrating technology into her teaching practice, illustrating her pedagogical knowledge within the professional knowledge bases of PCK. To further enhance learner engagement, Samantha proposed incorporating interactive games like crossword puzzles and charades. These activities would require learners to actively participate, addressing the issue of passive engagement. Through using the smartboard to display timers and puzzles, she can create a dynamic and interactive learning environment. This strategy aligns with the SAMR model's modification and redefinition levels, as technology would use to transform the learning experience.

Jade's pedagogical reasoning is evident in her ability to identify the strengths and limitations of the smartboard and her willingness to adapt her teaching strategies accordingly. She understands the importance of visual aids, immediate feedback, and active engagement in promoting learner understanding. Her suggestions for integrating games and using alternative annotation tools demonstrate her commitment to creating a dynamic and inclusive learning environment. Her reflections on learner engagement and the need to accommodate diverse learning styles highlight her deep understanding of pedagogical principles and her ability to apply them in a technology-rich classroom. She is demonstrating her PCK by identifying the best method of teaching the content, while dealing with the limitations of her own physical ability, and the learners attention span.

4.4.3 Insights drawn from the narratives derived from listening to audio recordings from interview conducted after the first lesson was taught at school 3.

During the interview, Zandaya highlighted several key aspects of her teaching practice using the smartboard as depicted in Appendix 22. She emphasized the affordances of the smartboard, particularly annotation, as being highly beneficial for facilitating learners' understanding of photosynthesis. She utilized PowerPoint presentations to visually display the structure of the chloroplast and engaged learners by annotating directly onto the slides during labelling activities. This aligns with the augmentation level of the SAMR model, where technology enhances traditional teaching methods. Furthermore, she incorporated diagrams, also aligning with augmentation in SAMR, to illustrate the process of photosynthesis, recognizing the importance of visual aids in learner comprehension.

Zandaya also mentioned the use of interactive quiz displayed on the smartboard, which provided immediate feedback to learners. This quiz, initially conducted individually and then in groups, demonstrated her ability to adapt her teaching strategies based on learner needs. This reflects her PCK specifically in the assessment knowledge professional knowledge base of PCK, as she uses smartboard to assess and provide feedback. The shift from individual to group work was a deliberate strategy to support struggling learners, showcasing her understanding of differentiated instruction and the benefits of peer learning, which also falls under pedagogical knowledge in the PCK.

Zandaya's pedagogical reasoning is evident in her reflective practice. She observed that learners were more engaged when she used the smartboard with visual aids, videos, and annotations compared to purely verbal instruction. This observation is evidenced by her description of the learners' behaviour during the lesson. She noted that they were *"fully engaged"* and that they were *"interactive,"* answering questions and interacting directly with the smartboard. When asked why she thought they were so engaged, Zandaya directly attributed it to the smartboard's use. She stated, *"I think the smartboard played a huge role."* She explained that when she only speaks verbally without using diagrams or visual aids, learners sometimes get *"confused"* or *"lost."* However, when she used the smartboard to play videos and annotate, she found that learners became *"more and more interactive."* This suggests a clear contrast in learner engagement levels depending on whether visual and interactive elements were present. Ultimately, she concluded that learners prefer visual aids over written or purely verbal instruction, as the latter can make them feel *"bored."*

Her observation led her to believe that learners prefer visual learning, and that the smartboard affordance enhance engagement. She recognized that learners became "bored" with just reading, highlighting her awareness of learners' diverse learning preferences. Her decision to use group work was also based on her observation of learners' struggles, demonstrating her ability to analyse learner needs and adjust her teaching strategies accordingly. Finally, her method of providing feedback by connecting learners' answers to the content slides demonstrates her attempt to address misconceptions and solidify understanding, reinforcing the content through visual representation.

4.5.1 Insights drawn from narratives derived from watching and analysing video recordings from the second lesson from school 1.

The lesson began with a review of photosynthesis, establishing the foundation that plants produce glucose, which is stored as starch. The researcher then outlined the objectives of the lesson: to identify the materials and reagents for a starch test, understand the significance of each step, and relate colour changes to the presence of starch as depicted in Appendix 9. The smartboard was utilized to display the various apparatus needed for the starch test, such as iodine solution, droppers, Bunsen burners, beakers, tweezers, test tubes, ethanol, and a tripod stand. The researcher engaged the learners by asking them to identify each piece of equipment and explain its purpose, demonstrating her pedagogical content knowledge. The smartboard served as a visual aid, allowing the researcher to point to each item and prompt responses. This use of the smartboard is an example of substitution in the SAMR model, as it replaces traditional methods of displaying equipment with a digital display but does not fundamentally change the teaching method.

A key point of the lesson was the explanation of the iodine solution's role as a reagent, changing colour from reddish-brown to blue-black in the presence of starch. The researcher used the smartboard to reinforce this concept, visually highlighting the expected colour changes. The smartboard also facilitated a discussion on safety procedures in the lab, displaying images of gloves, goggles, and lab coats as depicted in Figure 24. This figure shows a picture of a teacher using a smartboard to present and annotate a slide on laboratory attire, with handwritten circles and labels highlighting items like gloves, goggles, and a lab coat. This figure is important because it visually demonstrates the use of a smartboard to actively engage learners in a discussion about safety procedures, making the information more interactive and memorable.

Figure 24: A screengrab from video recording where the researcher is showing learners pictures of laboratory attires.

The researcher emphasized the importance of proper attire and safety measures when handling chemicals, explaining why certain clothing was inappropriate in a lab setting. The smartboard visuals helped reinforce these safety guidelines, making them more memorable for the learners. This is also substitution, as it replaces traditional posters or verbal explanations of safety procedures with digital images. The researcher's awareness of safety protocols and her ability to convey them showcased her pedagogical knowledge. Furthermore, the researcher then used an animation video displayed on the smartboard to walk through the steps of the starch test procedure. The animation visually demonstrated each step, from boiling the leaf in water to adding the iodine solution. The researcher paused the video at critical points to ask questions, ensuring the learners understood the purpose of each step. The smartboard supported this demonstration, allowing the learners to visualize the process and reinforce their understanding. The researcher's use of the smartboard to show the animation, combined with her questioning and explanations, made the abstract concept of the starch test more concrete and accessible.

The researcher explicitly states, *"I'll just display this animation video and then I'll take you through it."* This indicates that the smartboard was used to present a visual, animated representation of the starch test. Throughout the explanation, the researcher frequently refers to the visual content on the smartboard, using phrases like *"you see now they tell you," "do you see our tweezer?", "you see here they are showing you,"* and *"can you see?"*. This constant referencing confirms that the learners were actively observing the animation. Furthermore, a learner's request to *"bend our heads a bit"* because they could not see everything, and the subsequent *"do you see?"* questions from the researcher, directly prove the smartboard was the central point of visual focus. The use of a visual aid like an animation helped make the abstract, multi-step process of the starch test more concrete and accessible. Finally, at the end of the lesson, a learner is asked to come to the smartboard to write the chemical equation for photosynthesis, further demonstrating its interactive role in reinforcing content knowledge. These interactions highlight the smartboard's affordance as a crucial tool for visualization, guidance, and interactive learning during the demonstration.

This use of animation to visually demonstrate the procedure is an example of augmentation level of SAMR model, as the technology enhances the traditional teaching method by providing a dynamic visual representation. The researcher's strategic questioning and pacing showed her enacted PCK, as she adjusted her teaching in real-time based on learner responses and understanding. This also demonstrated her curricular knowledge by teaching the starch test procedure in the correct sequence.

Finally, the researcher used the smartboard to display a set of questions for a short assessment. The questions tested the learners' understanding of the starch test procedure and the underlying concepts. The smartboard allowed for easy display of the questions, and the researcher used it to write the chemical equation for photosynthesis, engaging the learners in the process. The smartboard was also used for a quick-paced vocabulary review, showing terms to the learners, and reinforcing the scientific vocabulary learned during the lesson. This interactive assessment and vocabulary review using the smartboard is an example of modification, as the technology allows for interactive elements and immediate feedback, transforming the assessment and review process. The integration of the smartboard throughout the lesson enhanced the learning experience, providing visual aids, interactive elements, and a platform for assessment.

The researcher's pedagogical reasoning was evident throughout the lesson, demonstrating a thoughtful and strategic approach to teaching the starch test. She began by establishing a solid foundation, reviewing photosynthesis to connect prior knowledge to the new concept. This revealed her content knowledge and her ability to deliver the lesson. She then clearly outlined the lesson's objectives, ensuring learners understood the purpose of the activity. When introducing the required apparatus, she used the smartboard to display images, substituting traditional methods with digital visuals. This allowed for immediate visual reinforcement as she prompted learners to identify and explain the function of each piece of equipment, revealing her pedagogical content knowledge by connecting the equipment to the scientific process. The researcher's explanation of the iodine solution's role, coupled with visual aids on the smartboard, reinforced the concept of chemical reactions and colour changes.

Her emphasis on safety procedures, using the smartboard to display appropriate lab attire, demonstrated her awareness of safety protocols and her ability to convey them successfully. She further augmented the lesson by using an animation to illustrate the starch test procedure, pausing strategically to ask questions and enhance learner understanding. This dynamic visual representation, coupled with her real-time adjustments based on learner responses, showcased her enacted PCK. Finally, she modified the assessment process by using the smartboard to display questions and facilitate an interactive vocabulary review, transforming traditional assessment methods. Her integration of the smartboard throughout the lesson, from visual aids to interactive elements, demonstrated her commitment to enhancing the learning experience and adapting her teaching methods to meet the learners' needs. Her strategic questioning, pacing, and use of technology revealed a deep understanding of how to make abstract concepts accessible and engaging for her learners.

4.5.2 Researcher's reflection on the lesson she delivered at school 1.

The researcher's ability to integrate digital visuals from the smartboard, like images and animations, to illustrate safety protocols and complex procedures demonstrated a strong foundation in collective PCK. The ease stemmed from the researcher's clear understandable explanation of how visual aids could bridge the gap between abstract concepts and concrete understanding, making the learning process more engaging and memorable for the learners. However, the difficulty appeared in ensuring that the smartboard affordances enhanced, rather than overshadowed, the core learning objectives. Maintaining a balance between leveraging the smartboard's affordances and fostering active learner participation required careful planning and execution. The risk of passive learning, where learners simply absorb information without critical thinking, had to be mitigated through strategic questioning and interactive activities.

Collaborative planning significantly influenced the researcher's enacted PCK by providing a platform for shared expertise and diverse perspectives as well as knowledge of learners and of context. Through collaborative discussions, the researcher was able to refine her lesson design, anticipate potential learner misconceptions, and develop targeted questioning strategies. This collaborative process fostered a deeper understanding of the subject matter and pedagogical approaches, leading to real-time adjustments during the lesson. The researcher's strategic pausing of the animation to ask questions, and her ability to adapt her pace based on learner responses, highlighted the impact of collaborative planning on her enacted PCK. The shared knowledge base allowed for a more nuanced approach to teaching, ensuring that the lesson was not only informative but also responsive to the learners' needs. Furthermore, the collaborative planning ensured curricular knowledge was applied, leading to the correct sequence of the starch test procedure.

The researcher's pedagogical reasoning was evident in her deliberate integration of digital visuals from the smartboard to enhance the teaching of safety protocols and complex procedures. She recognized the potential of these visuals to bridge the gap between abstract concepts and concrete understanding, demonstrating a strong foundation in collective PCK. However, she also critically considered the potential pitfalls, acknowledging the risk of the smartboard's affordances overshadowing the core learning objectives. This awareness prompted her to strategically balance the use of visuals with active learner participation. She employed strategic questioning and interactive activities to mitigate passive learning, reflecting a thoughtful approach to maximizing learning outcomes.

Furthermore, the researcher's pedagogical reasoning was deeply influenced by collaborative planning. Through shared expertise and diverse perspectives, she refined her lesson design, anticipated learner misconceptions, and developed targeted questioning strategies. This collaborative process fostered a deeper understanding of both the subject matter and pedagogical approaches, enabling real-time adjustments during the lesson. The researcher's ability to adapt her pace and strategically pause animations to ask questions demonstrated the impact of this collaborative planning on her enacted PCK. Finally, the collaborative planning ensured that curricular knowledge was appropriately applied, leading to the correct sequence of the starch test procedure, and thus showing the researcher's careful consideration of the lesson's content and its appropriate delivery.

4.5.3 Insights drawn from narratives derived from watching and analysing video recordings from the second lesson from school 2.

The researcher, in both School 1 and School 2, employed the smartboard as a central tool to facilitate the teaching of the starch test procedure. Both lessons began with a review of photosynthesis, establishing the essential link between glucose production and starch storage in plants. In both schools, the researcher systematically introduced the necessary apparatus and reagents for the starch test, utilizing the smartboard to display and identify each item. This consistent use of the smartboard for visual representation exemplified the substitution level of the SAMR model, replacing traditional methods of displaying equipment with a digital format. Similarly, both lessons emphasized the crucial role of iodine solution and the associated colour changes, reinforcing this concept with visual aids on the smartboard. Safety procedures were also addressed in both schools, with the researcher using the smartboard to display images of appropriate lab attire, again demonstrating substitution by replacing traditional posters or verbal instructions with digital visuals. Furthermore, both lessons used the smartboard to present the chemical equation for photosynthesis, aiding learners in understanding and writing it.

However, the lessons also diverged in their application of the SAMR model and their pedagogical approaches. In School 1, the researcher incorporated an animation video to visually demonstrate the starch test procedure, representing augmentation by enhancing traditional teaching methods with dynamic visuals. This was coupled with strategic questioning and pacing, demonstrating enacted PCK as the researcher adapted her teaching in real-time. In School 2, the researcher also used animation, but the lesson emphasized active engagement through questioning and discussion, with the smartboard used to record learner responses, also showing augmentation. The researcher constantly asked open-ended and probing questions like, *"What is this?"*, *"Why are we boiling the leaf?"*, and *"How do you write it?"*. The learners' responses, often short and direct, indicated that they were actively recalling and applying their knowledge. The researcher then used these responses to guide the conversation and correct misconceptions, for example, by asking, *"You put inside the iodine solution and then you squeeze it. So, this is called a dropper. It's a dropper."* This interactive questioning style is a key part of an active learning approach.

In School 1, the researcher used the smartboard for a quick-paced vocabulary review and an interactive assessment, representing modification by transforming traditional assessment methods. In School 2, a 30-second vocabulary game was implemented, which also represented modification, by using the smartboard to make the vocabulary review more interactive and engaging. Both schools also used the smartboard for reviewing the material.

Regarding the refined consensus model of PCK, the researcher's content knowledge was evident in both schools through the accurate presentation of scientific concepts and equations. Her pedagogical knowledge was demonstrated through her questioning techniques and facilitation of discussion in both schools. In School 1, her enacted PCK was showcased through real-time adjustments based on learner responses and understanding. In School 2, her enacted PCK was also observed through her adaptation of explanations based on learner feedback. In School 2, her collective PCK was also evident, as she drew on shared pedagogical strategies and knowledge with the three participating teachers. Her curricular knowledge was highlighted in both schools through the correct sequencing of the starch test procedure and the inclusion of key vocabulary. In School 2, her knowledge of learners was also evident as she tailored questions to gauge understanding. In School 2, her assessment knowledge was utilized to identify and address misconceptions. Both schools showed her PCK in action, as she adapted her teaching based on learner responses.

The researcher's pedagogical reasoning was evident throughout both lessons, demonstrating a thoughtful approach to teaching the starch test procedure. In both schools, she began by establishing a foundational understanding of photosynthesis, recognizing the importance of contextualizing the experiment within a broader scientific framework. She then carefully presented the necessary apparatus and reagents, utilizing the smartboard to provide clear visual representations. This decision reflected her understanding of how visual aids could enhance learner comprehension, particularly when dealing with abstract scientific concepts. She reasoned that by visually displaying the equipment and the chemical equation, she could substitute traditional methods, making the learning process more accessible. However, the researcher's reasoning extended beyond mere substitution. In School 1, she reasoned that incorporating an animation video would augment the learning experience by providing a dynamic visual demonstration of the starch test procedure. This decision indicated her awareness of the power of multimedia in engaging learners and clarifying complex processes. Furthermore, her strategic questioning and pacing in School 1 revealed her ability to adapt her teaching in real-time, demonstrating enacted PCK. She reasoned that by actively monitoring learner responses, she could adjust her instruction to address any misconceptions or areas of confusion.

In School 2, the researcher similarly utilized animation, but her pedagogical reasoning emphasized active learner engagement. She reasoned that by facilitating discussion and recording learner responses on the smartboard, she could create a more interactive and collaborative learning environment. This approach reflected her understanding of the importance of learner participation in constructing knowledge. Furthermore, her implementation of a 30-second vocabulary game in School 2 demonstrated her ability to modify traditional assessment methods, transforming them into engaging and interactive activities. She reasoned that this gamified approach would enhance learner motivation and retention of key vocabulary.

The researcher's reasoning also extended to her assessment practices. She recognized the importance of identifying and addressing learner misconceptions, as evidenced by her targeted questioning and analysis of learner responses in both schools. In School 2, she tailored questions to enhance understanding, demonstrating her knowledge of learners and her commitment to differentiated instruction. Her ability to draw on shared pedagogical strategies and knowledge with the three participating teachers in School 2 also revealed her collective PCK, highlighting her collaborative approach to teaching. Finally, throughout both lessons, the researcher's consistent use of the smartboard to review material demonstrated her understanding of the importance of reinforcing key concepts and providing opportunities for learners to consolidate their learning.

4.5.4 Researcher's reflection on the lesson she delivered at school 2.

Reflecting on the two teaching experiences, it's evident that while the core content remained consistent, the nuances of delivery and learner engagement varied significantly. The researchers teaching approach at School 2, while utilizing the smartboard similarly to School 1, leaned more heavily on interactive questioning and immediate feedback. The increased reliance on interactive questioning and immediate feedback at School 2 likely stemmed from the researcher's adaptation to the specific learner dynamics observed there. The learners at School 2 demonstrated a greater need for active participation, responded better to real-time reinforcement, and possessed a learning style that thrived on immediate clarification, prompting the researcher to adjust their pedagogical approach for optimal engagement and comprehension. This resulted in a more dynamic classroom environment, with learners actively participating and readily offering their insights.

I noticed a distinct difference in learner participation; at School 1, the learners seemed more comfortable voicing their thoughts and engaging in discussions. This could be attributed to the researcher's deliberate effort to address misconceptions in real-time and validate learner responses, fostering a sense of confidence and inclusion. In contrast, despite that School 2 also used visual aids and animations, the interaction felt slightly more structured and less spontaneous given that the learners were not too involved. The change in approach likely stemmed from an observation that actively addressing misconceptions and validating learner responses significantly boosted participation and confidence at School 1. By contrast, while visual aids are beneficial, they don't inherently foster the same level of interactive engagement. The shift towards real-time intervention and validation suggests a focus on creating a more dynamic and inclusive learning environment, prioritizing active participation over simply presenting information.

One significant deviation from the planned lesson occurred at School 1 when learners struggled with the Bunsen burner identification, prompting an impromptu discussion linking its function to familiar cooking experiences. This adaptation highlighted the importance of being flexible and responsive to learners' immediate needs. Lessons learned from these experiences include the critical role of interactive questioning in gauging understanding, the value of addressing misconceptions directly, and the necessity of adapting teaching strategies based on real-time learner feedback.

Comparing the SAMR model applications, in both schools the researcher utilized substitution by replacing traditional displays with the smartboard. In both schools, the researcher made use of the smartboard to record learner responses and provide immediate visual feedback moved beyond substitution into augmentation, enhancing the traditional notetaking process. Additionally, the vocabulary game that the researcher played with the learners represented modification, fundamentally transforming the assessment process into an engaging, interactive activity. Regarding the refined consensus model of PCK, the researchers demonstrated strong content knowledge and pedagogical knowledge.

This is based on the interaction between the researcher, the smartboard, and the learners. PCK is not simply knowing the subject matter or knowing how to teach. It is the intersection of the two. The refined consensus model suggests a developed and deeper understanding of how to teach specific content. Using the smartboard to record responses and give immediate feedback shows the researcher's ability to integrate technology to improve teaching. This demonstrates pedagogical knowledge, as it involves making informed decisions about teaching strategies. Furthermore, the vocabulary game transforming assessment into an engaging activity indicates a deep understanding of how to present content in a way that is both educational and engaging, showcasing both content and pedagogical knowledge. The researcher knew how to use the content of the vocabulary lesson, and how to use the technology of the smartboard and games to enhance the learning process. Therefore, the implementation of technology to enhance learning, as well as the interactive game, demonstrates an integration of subject matter and teaching strategies, which is the core of PCK.

In school 2, the researcher demonstrated an enacted PCK, adapting her teaching in real-time based on learner responses and leveraging her collective PCK by drawing upon shared pedagogical strategies. Furthermore, the researcher displayed an appropriate curricular knowledge by teaching the starch test in the correct order. This signified that the researcher understands and adheres to the established sequence of steps within the curriculum for conducting the starch test. Curricular knowledge, in this context, refers to a teacher's understanding of the subject matter's organization and the prescribed sequence of topics or activities. This includes knowing the content itself, the order in which it should be taught, and the rationale behind that order. In the case of the starch test despite that the experiment was not done physically but was shown to the learners using a video, there are specific procedural steps that, if deviated from, could result in inaccurate or unreliable results. Therefore, knowing and implementing the correct order demonstrates that the researcher possesses the necessary curricular knowledge to deliver the lesson as intended by the curriculum.

The researcher's pedagogical reasoning was evident in her dynamic adaptation to the varying learner needs across the two schools. At School 1, the researcher recognized the learners' comfort in voicing their thoughts and leveraged this by fostering a classroom environment that prioritized real-time intervention and validation. This was exemplified by the impromptu discussion about Bunsen burner functionality, linking it to familiar cooking experiences, demonstrating flexibility and responsiveness. The researcher's decision to utilize the smartboard for recording responses and providing immediate feedback, and the implementation of the vocabulary game, reflected a deliberate effort to integrate technology to enhance learning and transform assessment into an engaging activity. This approach showcased a deep understanding of PCK, where subject matter and teaching strategies were intertwined. The researcher's ability to adjust her teaching in response to learner struggles, such as the Bunsen burner identification, illustrated her capacity for pedagogical reasoning, moving beyond simply delivering content to facilitating meaningful learning experiences.

At School 2, the researcher's pedagogical reasoning manifested in her ability to adapt her teaching in real-time based on learner responses and leverage collective PCK by drawing upon shared pedagogical strategies. The shift towards more interactive questioning and immediate feedback, despite the learners being less spontaneously interactive, demonstrated the researcher's observation of the learner dynamics and her capacity to adjust her pedagogical approach for optimal engagement and comprehension. Furthermore, the researcher's adherence to the correct procedural order for teaching the starch test, even when using a video, highlighted their strong curricular knowledge. This indicated an understanding of the subject matter's organization and the prescribed sequence of topics, ensuring that the lesson was delivered as intended by the curriculum. These adaptations and decisions underscored the researcher's ability to apply her PCK and curricular knowledge in diverse learning environments, showcasing a refined understanding of how to teach specific content.

4.5.5 Insights drawn from narratives derived from watching and analysing video recordings from the second lesson from school 3.

This transcript documented a life sciences lesson where a researcher guided learners through a practical investigation of photosynthesis, specifically the starch test as depicted in Appendix 13. The researcher utilized a variety of teaching strategies, including questioning, demonstrations, and the use of a video and diagram displayed on a smartboard, to engage the learners and reinforce their understanding of the process. The researcher began by reviewing the theoretical aspects of photosynthesis, including its definition, the organelle involved, its importance, and the light and dark phases. This review, utilizing the smartboard to display and discuss existing information, represented substitution in the SAMR model, as it replaced traditional methods of reviewing theory with digital display. This foundational knowledge is crucial for the learners to grasp the purpose of the practical investigation. The smartboard affordances became a valuable tool here, likely displaying diagrams or summaries of these processes, allowing learners to visualize and consolidate their understanding. This displays the researchers content knowledge, as they were able to accurately convey the details of photosynthesis.

The focus then shifted to the starch test, a practical method to demonstrate the presence of starch, a product of photosynthesis, in leaves. The smartboard was used to show a video animation of the starch test procedure. The researcher implemented augmentation by using the smartboard to show a video, as the technology enhanced the traditional lecture by providing dynamic visual representation of the procedure. The visual aid allowed learners to observe each step of the experiment in a clear and concise manner. Furthermore, the researcher strategically paused and replayed sections of the video, ensuring learners understood the significance of each step, such as boiling the leaf to soften it and using a water bath to prevent the flammable alcohol from catching fire. The smartboard's ability to display dynamic visual content played a huge role in enhancing the learners' comprehension of the procedural aspects of the experiment. This demonstrates the researcher’s pedagogical knowledge, as they were able to select and utilize smartboard affordances to enhance the lesson. The researchers personal PCK was showcased in the utilization of the smartboard to improve the lesson.

Following the video, the researcher displayed a diagram representing the steps of the starch test on the smartboard. The use of a static diagram on the smartboard to reinforce the video content is a further example of augmentation, as it was building upon the initial video demonstration. This static visual reinforcement was used to solidify the learners' understanding of the process. The researcher used the diagram to repeat key concepts, such as the colour change of iodine solution in the presence of starch and the importance of the water bath. The smartboard's capacity to display both dynamic video and diagrams provided a versatile platform for reinforcing different aspects of the lesson. This also showed curricular knowledge, as the researcher was following a procedural experiment that is a standard within the science curriculum. The collective PCK is reflected in the researcher’s use of smartboard that was as agreed upon during the planning process to enhance learning.

Additionally, the researcher also utilized the smartboard to display questions related to the experiment, facilitating a classroom discussion. This interactive approach, using the smartboard to display questions and promote discussion, represents modification, as the technology allows for a significant redesign of the learning activity, making it more interactive and engaging than traditional question and answer sessions. The smartboard's ability to display text and images simultaneously allows for a seamless integration of visual aids and discussion prompts. The researcher engaged the learners in an activity, where they had 30 seconds to describe concepts related to photosynthesis and the starch test.

This activity, facilitated by the smartboard displaying keywords, tests the learners' ability to recall and articulate their understanding under pressure. This timed recall activity, facilitated by the smartboard, represents redefinition, as the technology allowed for a novel learning experience that would not be possible without it, fundamentally changing the way learners engage with the material. This demonstrates the researcher’s assessment knowledge, as she was able to create an activity that enabled the learners to show their understanding in a short amount of time. This also shows the researchers’ knowledge of the learners, as she was able to adapt their lesson to engage the learners. The enacted PCK is displayed in the researcher’s ability to use the smartboard in real time to adapt the lesson to the learner responses and interactions.

The researcher demonstrated a clear pedagogical reasoning process by building on learners' prior knowledge and using various teaching aids to explain complex concepts. She began the lesson by connecting the new information to what the learners already knew. For instance, she asked, *"remember when you were doing plant tissues in grade 10 you were taught about Xylem and phloem,"* to link the function of phloem to the storage of food, which is the product of photosynthesis. This shows she understood the importance of activating prior knowledge. After establishing a foundation, the researcher used a smartboard to visually demonstrate the starch test procedure. She played a video animation of the experiment, pausing it strategically to explain each step. For example, she stopped the video and asked, *"why are you boiling the leaf for five minutes? You must know,"* directly addressing a common question and highlighting its importance. This shows she knew how to use technology to enhance understanding. The researcher further solidified her pedagogical content knowledge by reinforcing the video content with a static diagram. She explicitly stated, *"this diagram here is just a representation of that video,"* and then walked the learners through the steps again. She pointed to different parts of the diagram, like the Bunsen burner, beaker, and petri dish, to ensure the learners understood the apparatus and the procedure. This dual approach using both dynamic and static visuals shows her ability to select and implement appropriate teaching materials to reinforce learning.

The researcher's curricular knowledge was evident in her adherence to the standard science curriculum, guiding learners through a procedural experiment common in life sciences. The researcher also demonstrated a strong understanding of assessment, creating a timed recall activity that allowed learners to showcase their understanding under pressure. This activity, facilitated by the smartboard, highlighted ability to create different learning experiences, reflecting a redefinition of traditional learning activities. Finally, the researcher's knowledge of learners was apparent in her ability to adapt the lesson in real time, responding to learner interactions and responses. This enacted PCK, demonstrated by her flexible use of the smartboard, allowed her to personalize the lesson and maximize learner engagement. Overall, the researcher's pedagogical reasoning was characterized by a thoughtful integration of content, pedagogy, and technology, aimed at fostering deep understanding and engagement among the learners.

4.5.6 Researcher's reflection on the lesson at school 3.

While the core content remained consistent, the teaching approaches varied significantly, impacting learner engagement and interaction. At School 2, the lesson was structured and methodical, heavily reliant on the smartboard for visual aids and structured questioning. This approach, while it was useful in conveying information, sometimes felt rigid, limiting spontaneous learner interaction. Schools 1 and 3, however, displayed a more dynamic and interactive style. In these schools, the researcher readily adapted her teaching based on real-time learner responses, fostering a more engaging and participatory environment. For instance, the use of timed vocabulary games and interactive discussions, particularly in School 3, significantly boosted learner involvement.

The difference in learner participation was intense; schools 1 and 3 saw more enthusiastic responses and deeper engagement, likely due to the more interactive teaching strategies. I noticed that in schools 1 and 3, if a learner was struggling with a concept, the researcher would adapt their explanation to meet the learner's understanding. This was not as prevalent in school

2. This points to the complexity of educational interactions. Even though the same researcher taught all the three schools the same lesson, the dynamics within each school setting were not the same. Factors beyond the researcher's consistency have influenced the application of adaptive teaching strategies. These factors included the pre-existing classroom culture, the learners' prior experiences, and the subtle differences in the physical environment. This means that during the planning process, the researcher and the participating teachers have overlooked details of a classroom, learning space, or school environment that have significantly impacted the learning process.

Furthermore, it is possible that the researcher, consciously or unconsciously, adjusted their teaching style based on the observed responses of learners in each school. In schools 1 and 3, the immediate positive feedback and engagement might have encouraged the researcher to continue adapting their explanations. Conversely, in school 2, a less enthusiastic or slower response might have led the researcher to maintain a more rigid instructional approach. Furthermore, differences in learner demographics, such as prior academic preparation or socio-economic backgrounds, could also play a role. Even if the researcher intended to maintain a uniform approach, the nuanced interactions within each classroom could lead to divergent outcomes. Deviations from the planned lesson occurred mainly in schools 1 and 3, where the researchers responded to learner misconceptions and adjusted their pacing accordingly. This flexibility, while requiring on-the-spot thinking, ultimately enhanced the learning experience. The key lesson learned is the importance of adaptability and learner-centred teaching. While structured lesson plans are essential, the ability to deviate and respond to learner needs is crucial for instruction.

When comparing the implementation of the SAMR model across the schools, the level of smartboard affordances integration varied. At school 2, the researcher primarily operated at the substitution and augmentation levels, using the smartboard to replace traditional methods and enhance visual presentations. At school 1 and 3, however, the researcher progressed further into modification and redefinition. At school 1 and 3, the researcher’s interactive note-taking and timed vocabulary game demonstrated a shift towards transforming the learning experience, leveraging the smartboard affordances for interactive and dynamic activities. Added to this, the timed activity across all three schools demonstrated redefinition.

In terms of the refined consensus model of PCK, the researcher demonstrated a content knowledge and pedagogical knowledge. However, the researcher’s enacted PCK varied significantly. At schools 1 and 3, the researcher showcased a greater ability to adapt her teaching in real-time, responding to learner misconceptions and tailoring explanations. This was evident in her flexible use of the smartboard and their ability to facilitate interactive discussions. Furthermore, at schools 1 and 3, the researcher was more skilful at utilizing assessment knowledge to identify and address learner misconceptions, demonstrating a deeper understanding of how to test and improve learner understanding. Furthermore, the researcher at schools 1 and 3 also displayed a stronger knowledge of her learners and was able to adapt lessons to meet the needs of the learners. The researcher displayed curricular knowledge in all three schools; however, the researcher was able to use the collective PCK, which was developed during planning, more in school 1 and 3 more than in school 2.

The researcher's pedagogical reasoning revealed a complex interplay between planned instruction and real-time adaptation. Initially, the researcher demonstrated strong content and pedagogical knowledge across all three schools, evidenced by the consistent lesson delivery and the use of the SAMR model for smartboard integration. However, the enacted PCK, or the practical application of this knowledge, diverged significantly. In Schools 1 and 3, the researcher exhibited a heightened ability to adapt their teaching based on immediate learner responses, indicating a deeper integration of assessment knowledge and knowledge of learners. This adaptability was seen in the flexible use of interactive activities, such as timed vocabulary games and dynamic discussions, and in their capacity to adjust explanations to address specific misconceptions.

The researcher recognized and responded to the distinctions of each classroom environment, demonstrating a capacity to move beyond rigid lesson plans and embrace learner-centred teaching. This flexibility, while demanding quick thinking, ultimately enhanced the learning experience. Conversely, in School 2, the researcher maintained a more structured and less adaptive approach, relying heavily on the smartboard for visual aids and structured questioning. This rigidity suggested a less developed ability to integrate assessment knowledge and knowledge of learners in real-time. The researcher's experience across the three schools highlighted the importance of recognizing and responding to the dynamic nature of educational interactions, emphasizing that instruction requires a balance between structured planning and flexible adaptation. It also showed that even with careful planning, unpredicted factors in the environment can greatly affect the learning experience.

4.6.1 Narratives drawn from listening to feedback session derived from the second lesson taught at School 1.

During the interview, Jade highlighted several key points regarding the researcher's use of the smartboard as depicted in Appendix 17. She noted the researcher used the presentation affordance to engage learners, enhancing their understanding through visual aids and guiding the lesson's flow. Jade pointed out that the researcher's use of the smartboard's annotation feature was a key part of her pedagogical content knowledge (PCK). This feature enabled the real-time addition of new information during the lesson, as Jade states, *" you also used annotation to add all the information that there was not on the presentation already, to add all the information again, that was being mentioned by the learners."* The ability to add information on the PowerPoint presentation (using a stylus) from learners' contributions demonstrated the researcher's skill in tailoring the technology to the dynamic nature of classroom discussion. The integration of this affordance also *"simultaneously allowed you to use the writing and the erasing function,"* further showcasing the researcher's use of the smartboard to facilitate an interactive and responsive learning environment.

Jade acknowledged the successful differentiation of instruction, citing the use of videos and diagrams which catered to auditory and visual learners, respectively. This demonstrated the researcher's understanding of diverse learning needs. The videos and diagrams represent SAMR at the Substitution and Augmentation levels, as they enhanced existing teaching methods. She also suggested the potential for interactive simulations to engage kinaesthetic learners, though time constraints might limit their use. In terms of providing immediate feedback and remediation, Jade mentioned the researcher's use of classwork displayed on the smartboard, where learners could annotate and receive instant feedback. The 30-second academic game, using a stopwatch feature, also provided quick feedback on learner understanding. These methods again highlight the researcher's PCK, as it shows an understanding of assessment strategies. The classwork annotation would fall under SAMR's Augmentation while the timing of the academic game would be considered Modification as it changes the delivery of feedback.

Jade suggested improvements, such as integrating internet connectivity for visual searches and utilizing drag-and-drop activities for diagram labelling. She also recommended greater learner collaboration using personal devices and learning management systems like Google Classroom, allowing for real-time tracking and feedback. This demonstrates the researcher's potential for further growth in technology integration, moving towards SAMR's Redefinition level.

The researcher's pedagogical reasoning, as inferred from Jade's observations, involved a conscious effort to utilize the smartboard affordances to enhance engagement and cater to diverse learning styles. The researcher adapted the technology to present content visually, facilitate interaction, and provide immediate feedback. Jade’s feedback, however, implied that the researcher's approach was somewhat isolated, and that greater integration of collaborative tools and activities could further enhance learning. This indicates a reflective practitioner, open to feedback and seeking to refine their approach to technology integration.

4.6.2 Narratives drawn from listening to feedback session derived from the second lesson taught at School 2.

Based on the interview sessions, both Jade and Samantha highlighted several key points regarding the researcher's use of the smartboard as depicted in Appendix 20. Jade, from School 1, emphasized the researcher's use of presentation affordances, annotation, and gamified affordances to create an interactive learning environment. She noted the use of videos and diagrams, aligning with the Substitution and Augmentation levels of the SAMR model, to cater to auditory and visual learners. Jade also pointed out the researcher's utilization of the smartboard for immediate feedback through classwork and a 30-second game, with the use of PowerPoint presentations. Jade suggested enhanced collaboration through learner device integration and Google Classroom, indicating a desire for Modification and Redefinition within the SAMR framework. Jade's pedagogical reasoning, highlighted the researcher's ability to engage learners, differentiate instruction, and provide immediate feedback, despite initial limitations in fully utilizing the smartboard's capabilities.

Samantha, from School 2, similarly acknowledged the researcher's use of pictures and videos (Substitution and Augmentation of SAMR) to illustrate the photosynthesis experiment, particularly given the school's lack of a lab. She praised the researcher's use of the 30-second game for assessing learner understanding and emphasized the differentiation of instruction through varied visuals and multimedia. Like Jade, Samantha noted the researcher's provision of immediate feedback through annotated classwork and a QR code activity. She highlighted the integration of the smartboard and the PowerPoint presentation, emphasizing its clarity and the researcher's facilitation during video playback. Samantha, also confirmed that the researcher facilitated learning and assessment through the smartboard, considering the diverse learning needs of the learners.

Comparing the two schools, both Jade and Samantha observed the researcher's use of PowerPoint presentations, videos, and annotation to enhance learning. They both highlighted the researcher's efforts to provide immediate feedback and differentiate instruction, despite the researcher’s inexperience in using the smartboard. However, Jade suggested more advanced integration through collaboration and Google Classroom, while Samantha focused on the researcher's use of available resources. Both sessions show that the researcher used the smartboard to engage learners and provide immediate feedback. Both teachers highlighted the use of visual aids and videos, indicating a similarity in teaching approaches across the two schools. They also both highlighted the use of the 30 second game to engage learners and provide immediate feedback.

4.6.3 Narratives drawn from listening to feedback session derived from the second lesson taught at School 3.

Based on the interview sessions, Jade, Samantha, and Zandaya highlighted several key aspects of the researcher's use of the smartboard as depicted in Appendix 23. Jade from school 1 emphasized the researcher's use of presentation affordances, annotation, and gamified affordances to create an interactive learning environment. She noted the researcher's use of videos and diagrams, aligning with the Substitution and Augmentation levels of the SAMR model, to cater to auditory and visual learners. Jade also pointed out the use of classwork and interactive games, like the 30-second word game, for immediate feedback and remediation, and suggested integrating Google Classroom for better collaboration and real-time feedback. Samantha from school 2 similarly acknowledged the researcher's use of pictures, diagrams, and muted videos to compensate for the lack of a physical lab, making the abstract concept of photosynthesis more concrete. She particularly praised the interactive 30-second game for testing learners' understanding and the immediate feedback provided through annotation and displayed answers on the smartboard. Zandaya from school 3 also highlighted the use of visual aids, interactive activities, and the 30-second game in engaging learners and catering to diverse learning styles. She emphasized the crucial role of the smartboard in providing visual representations of experiments, especially given the school's lack of lab facilities.

Zandaya observed that the teacher's use of Mentimeter (as depicted in Figure 25) was effective for assessing understanding through *"anonymous polling that was done and also quizzes after* *the lesson."* This approach allowed learners to *"express their comprehension without any pressure"* and moved towards modification. The researcher's use of this tool demonstrated her assessment knowledge and her ability to provide real-time feedback, a key aspect of her enacted PCK. Zandaya also suggested that the tool could be used more strategically to assess prior knowledge, stating that the teacher *"could have done brainstorming first before introducing"* the topic, further highlighting the potential for the Mentimeter to be a transformative tool in the classroom. This suggests a move toward modification because it fundamentally changed how feedback was gathered and provided, moving away from traditional, more public methods of questioning and toward a more private, real-time assessment.

Figure 25 below shows a smartboard displaying a Mentimeter presentation, which is a live poll or quiz asking learners to define photosynthesis. This figure is important because it demonstrates a way for teachers to quickly and anonymously collect a range of learner responses in real time, which can then be used to assess their understanding and guide the lesson.

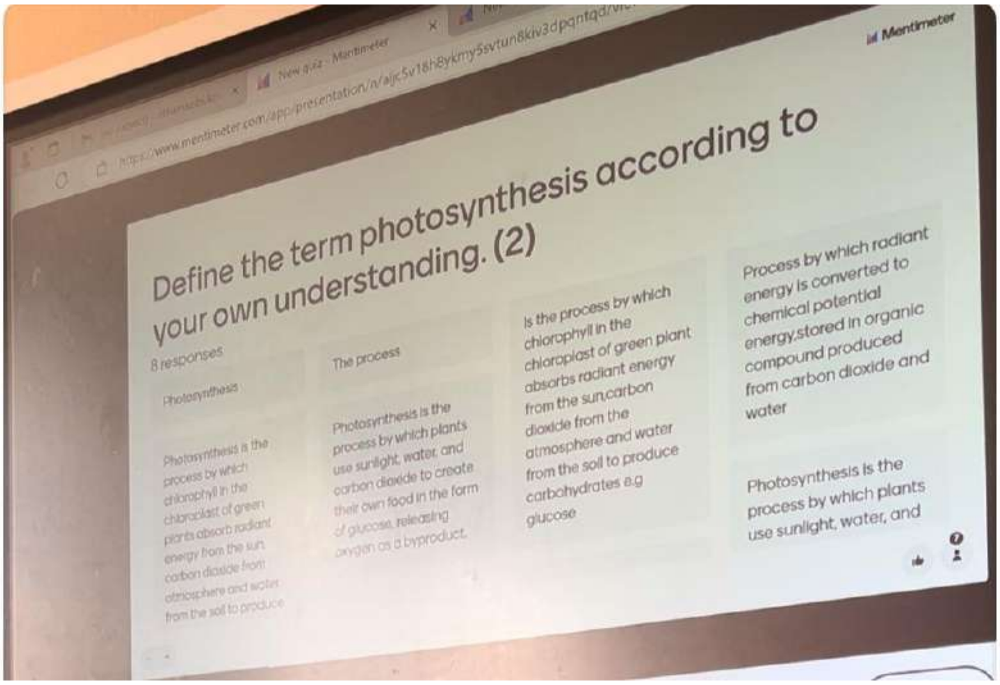

Figure 25: Learner’s anonymous responses on Mentimeter.

The researcher's pedagogical reasoning, as gleaned from these feedback sessions, demonstrated a focus on creating interactive and engaging learning environments. The researcher strategically employed the smartboard's affordances to address the specific needs of the learners, such as compensating for the lack of a lab through video demonstrations in school 3 and providing immediate feedback through interactive activities. The researcher's use of diverse instructional strategies, including visual aids, annotation, and gamification, indicates a developing PCK that considers learners' diverse learning styles. The researcher's ability to adapt and utilize the smartboard to facilitate learning, despite potential time constraints and limited initial expertise, highlights a commitment to enhancing the learning experience. The interviews revealed the researcher's PCK, as she was able to utilise the smartboard to enhance the learners' understanding of the subject matter and was able to utilise the smartboard to address the diverse learning needs of the learners.

Comparing the feedback from school 1 and school 2, there are notable similarities and differences. In both schools, the researcher used the smartboard to provide visual aids, interactive activities, and immediate feedback. Both Jade and Samantha praised the researcher's use of videos and diagrams (SAMR) to cater to different learning styles. However, Jade suggested integrating Google Classroom for better collaboration and real-time feedback, while Samantha focused more on the effectiveness of the existing strategies, particularly the use of muted videos and annotation. In both schools, the 30 second game was seen as a positive. The use of Mentimeter was only mentioned in school 3 and was seen to engage with the learners and gain feedback. In all three participating schools the researcher used annotation on the smartboard, and PowerPoint presentations to aid in the lesson.

4.7 Overall insights on how to integrate smartboard affordances drawn from the analysis of interview transcripts.

Across all three schools, the teachers recognized the smartboard affordances play a major role in enhancing visual learning and engagement. They valued the annotation affordance for its ability to dynamically illustrate complex concepts and provide immediate feedback. The use of PowerPoint presentations, enriched with images and diagrams, was deemed crucial for catering to diverse learning styles. Teachers also highlighted the effectiveness of interactive games and quizzes, facilitated by the smartboard, in reinforcing learning and promoting active participation. Furthermore, the teachers noted the smartboard affordances play a huge role in addressing misconceptions by visually comparing related concepts. The ease of integrating digital tools like Mentimeter and Google Forms for assessment and feedback was also appreciated, demonstrating the smartboard's adaptability in supporting various pedagogical strategies.

4.8 Overall oversights and missed opportunities drawn from the analysis of the interview transcripts.

Despite the recognized benefits, several oversights and missed opportunities were evident. Teachers sometimes struggled to fully utilize interactive features like polls and virtual labs, indicating a need for training and support. Time constraints often led to the exclusion of kinaesthetic activities, limiting the ability to cater to all learning styles. While teachers used the smartboard affordances for visual and auditory learning, opportunities to incorporate more hands on, collaborative activities were often missed. There was a tendency to rely heavily on PowerPoint presentations and annotations, potentially overlooking the integration of learning management systems like Google Classroom for real-time progress tracking and enhanced collaboration. Some teachers expressed a lack of familiarity with certain smartboard affordances, such as Mentimeter, highlighting the need for ongoing professional development. Finally, although teachers recognized the importance of immediate feedback, the full potential of the smartboard affordance to provide personalized and detailed remediation was not always apprehended.

4.9 Overall insights on how to integrate smartboard affordances drawn from the analysis of video transcripts.

Across all three schools, the smartboard proved to be a valuable tool for enhancing visual learning in science lessons. Teachers utilized the smartboard to display diagrams, animations, videos, and chemical equations, making abstract concepts like photosynthesis and the starch test more accessible to learners. The ability to annotate directly on the screen, highlight key points, and display real-world examples like micrographs of chloroplasts significantly improved learners' engagement and understanding. The smartboard facilitated interactive questioning, allowing teachers to check for understanding and guide learners through complex processes. In lessons focused on the starch test, animations displayed on the smartboard provided clear, step-by-step visual guides, compensating for the absence of physical experiments. Furthermore, the smartboard's capacity to display both dynamic video and static diagrams offered a versatile platform for reinforcing different aspects of the lesson. The use of the smartboard for assessment, including quick vocabulary reviews and displaying questions, streamlined the learning process and provided immediate feedback.

4.10 Overall oversights and missed opportunities drawn from the analysis of video transcripts.

While the smartboard was generally used, there were instances where its full potential was not realized. Some teachers focused primarily on using the smartboard as a digital whiteboard, displaying static images and text without fully leveraging its interactive capabilities. For example, in some lessons, opportunities for drag-and-drop activities, labelling exercises, or collaborative mind mapping were missed. In School 3, technical difficulties significantly disrupted the flow of the lesson, highlighting the importance of ensuring teachers are adequately trained and prepared to troubleshoot technical issues. There were also instances where teachers did not fully utilize the smartboard's ability to cater to diverse learning styles. While visual aids were prevalent, opportunities to incorporate auditory or kinaesthetic elements through interactive simulations or virtual labs were not always explored. Additionally, while the smartboard was used to display questions, the immediate feedback and tracking learner progress through interactive quizzes or polls was not consistently utilized.

A significant missed opportunity was the lack of consistent integration of the smartboard for collaborative learning activities. In some lessons, learners could have used the smartboard to create presentations, draw diagrams, or solve problems as a group, fostering teamwork and deeper understanding. The smartboard could have also been used to connect the classroom to external resources, such as virtual field trips or online databases, expanding the scope of learning beyond the classroom walls. Furthermore, there were missed opportunities to use the smartboard for data visualization and analysis. For instance, in lessons related to photosynthesis, learners could have used the smartboard to graph data on the effects of light intensity or carbon dioxide concentration on the rate of photosynthesis. Moreover, the smartboard could have been used to facilitate peer teaching, where learners use the interactive features to explain concepts to their classmates. Finally, consistent use of the smartboard to create a digital learning portfolio or resource library for learners to access outside of class time was not observed. This would have helped reinforce classroom learning and improve learners' engagement.

4.11 Building on PCK: Aligning Smartboard Affordances with SAMR Model for Transformative Learning Experiences.

The refined consensus model of PCK and the SAMR model can be related through the lens of how teachers integrate smartboard affordances into their photosynthesis lessons. The refined

PCK model emphasizes the interconnectedness of content knowledge, pedagogical knowledge, and technological knowledge, highlighting how teachers must understand and integrate these domains to enhance learner learning. In this study, collaborative lesson planning, a form of collective PCK, demonstrated how teachers collectively determined appropriate smartboard affordances to align with curriculum standards and learner needs. This process directly relates to the SAMR model, as teachers moved beyond mere substitution (using the smartboard as a digital whiteboard) to augmentation (annotating diagrams, using interactive quizzes), and modification (gamified learning, real-time feedback). For instance, using annotation tools to explain complex chloroplast structures directly modifies traditional teaching methods, enhancing visual understanding.

Moreover, the interviews revealed how teachers transitioned from basic smartboard usage to more transformative applications. In the substitution phase, teachers primarily used the smartboard to display PowerPoint presentations. As they gained experience and confidence, they moved towards augmentation by incorporating interactive elements like quizzes and videos. Modification occurred when teachers used the smartboard for real-time feedback and gamified learning, such as the 30-second game, which significantly altered the learning experience. Finally, although not fully realized, the potential for redefinition was evident in suggestions for integrating learning management systems like Google Classroom. This would allow for collaborative learning beyond the classroom, transforming the learning environment. For example, the use of Mentimeter, when fully understood, could have redefined the feedback process, allowing for anonymous and immediate polling, thereby changing the dynamics of classroom interaction.

The integration of prior knowledge and pedagogical approaches also illustrates this relationship. Teachers considered learners' prior knowledge and used diverse strategies like visual aids, real-world connections, and vocabulary reinforcement. These pedagogical choices were then amplified by the smartboard, moving beyond simple substitution to augmentation and modification. For instance, using a picture of a spinach garden to connect photosynthesis to real-world applications, coupled with annotations and interactive quizzes on the smartboard, transformed the learning experience, moving it from a passive to an active process. The oversights and missed opportunities, such as the limited use of interactive features and hands-on activities, highlight the need for continuous professional development to fully realize the redefinition phase of the SAMR model. This aligns with the refined PCK model, which stresses the importance of ongoing learning and adaptation to integrate technology into teaching practices.

The pedagogical reasoning centred on the dynamic interplay between smartboard affordances integration and established teaching practices within the context of photosynthesis lesson. Teachers are depicted as navigating a progression from basic technology substitution to more transformative modifications, driven by a desire to enhance learner learning. This progression was not merely a technical one; it was deeply rooted in pedagogical considerations. Teachers consciously aligned smartboard affordances with curriculum standards and learner needs, demonstrating a thoughtful approach to content delivery. They were actively engaged in selecting and adapting technological tools to amplify pedagogical strategies, such as the use of visual aids and real-world connections, ensuring that these strategies were not simply replicated digitally, but rather, significantly enhanced.

Furthermore, the emphasis on collaborative lesson planning highlighted the social and collective nature of pedagogical reasoning. Teachers were shown to share expertise and collectively determine appropriate technological applications, reflecting a shared understanding of teaching practices. This collaborative approach underscored the importance of professional learning communities in fostering pedagogical innovation. The teachers were aware of the need to adapt teaching methods to suit diverse learner needs, as evidenced by the incorporation of interactive quizzes, gamified learning, and real-time feedback. Teachers were not simply adopting technology for its own sake, but rather, strategically used it to create engaging learning experiences. The consideration of prior knowledge and the deliberate use of diverse teaching strategies, such as vocabulary reinforcement and visual representations, showcased a deep understanding of pedagogical principles and their application in a technology-rich environment.

The recognition of oversights and missed opportunities, such as the limited use of smartboard affordances and the potential for redefinition through learning management systems, demonstrated a commitment to continuous improvement. Teachers were portrayed as reflective practitioners, constantly evaluating and refining their teaching practices to better integrate technology and enhance learner learning. This aligned with the refined PCK model's emphasis on ongoing learning and adaptation, highlighting the importance of continuous professional development in fostering technology integration. The aspiration to move towards the redefinition phase of the SAMR model, using tools like Mentimeter, illustrates a desire to fundamentally transform the learning environment and create more collaborative and engaging educational experiences.

Figure 26 integrates the concepts of pedagogical content knowledge and the SAMR Model to explain how knowledge domains influence teaching practices and technology integration. This figure is important because it provides a conceptual framework for understanding how a teacher's collective and personal knowledge informs their enacted practice, which is then applied using technology (smartboard affordances) at various levels, from Substitution to Redefinition.

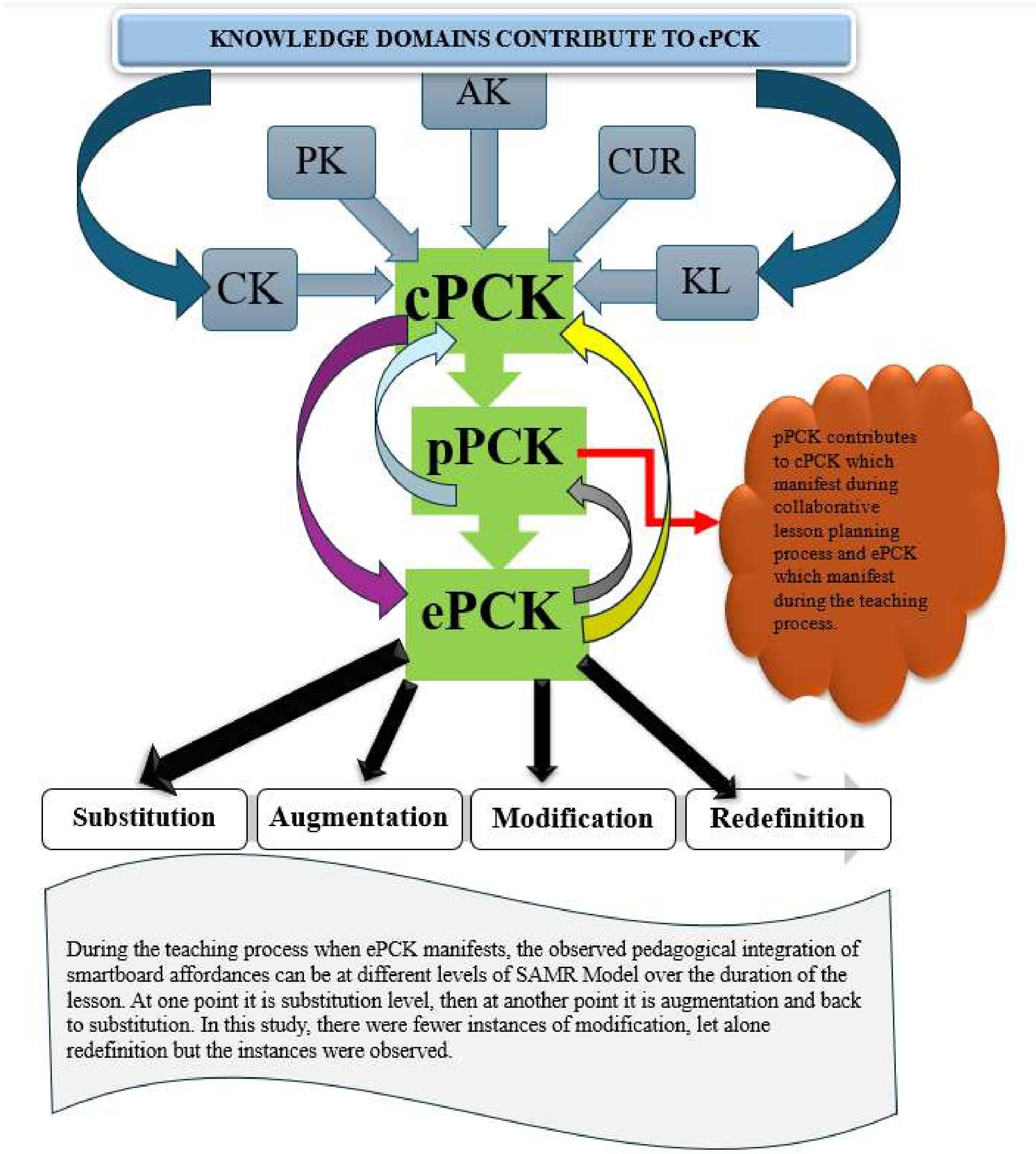

Figure 26: The connection between Refined Consensus Model of PCK and SAMR Model.

Chapter 5

Conclusion, Recommendations, Limitations of the study and Implications of the study

5.0 Introduction

This research investigated the integration of smartboard affordances in Grade 11 Life Sciences classrooms, specifically focusing on the teaching of photosynthesis. The study addressed the common misconception that merely providing smartboards automatically enhances instructional quality, especially for complex topics. It aimed to investigate and suggest a practical framework for teachers to strategically leverage smartboard affordances, moving beyond basic usage to truly transform pedagogical practices. The research examined the steps teachers followed to integrate smartboard affordances with pedagogy, the extent to which they did so, and how these affordances were incorporated into teaching photosynthesis. Essentially, the study explored how teachers could utilize smartboard affordances to improve teaching and learning, rather than simply using them as digital projectors. The focus was on providing South African teachers with actionable strategies to enhance their teaching of photosynthesis through the thoughtful integration of smartboard affordances. The study further analysed the challenges teachers faced when incorporating smartboard affordances, and the implications of their usage on PCK. Ultimately, this research aimed to highlight the significance of moving beyond substitution in smartboard integration, advocating for a deeper, transformative approach that involves modification and redefinition to leverage smartboard affordances to improve teaching and learning outcomes. The research also underscored the importance of a collaborative approach to achieve smartboard integration. It was found that when teachers engaged in collaborative planning and shared best practices, they were better equipped to move beyond simple substitution. This collaborative environment facilitated an understanding of how to leverage the smartboard affordances to enhance learner engagement and promote active learning, ultimately leading to improved teaching and learning outcomes.

5.1 Summary of the study

This research examined how smartboards, a common digital teaching tool, are used in Grade 11 Life Sciences classes to teach photosynthesis. Essentially, this research points out that simply having smartboards in classrooms does not automatically improve teaching, particularly for complex topics like photosynthesis. The study aimed to give teachers a possible plan for using smartboards to make lessons more effective, showing how the smartboard can be tailored to specific topic. Instead of a generic approach, they are looking deep into photosynthesis to show how it can be done better. The main point is that knowing how to use smartboard will not be of too much help, teachers need to learn how to use the smartboard to improve how they teach and how their learners learn. Teachers need to learn how to integrate the smartboard into their lessons, rather than just using them as a projector. This study aimed to provide a practical framework, especially for South African teachers, to help them move beyond basic usage of the smartboard enhancing their teaching of photosynthesis.

The research design employed multiple case studies, chosen to allow for in-depth exploration of varied teaching practices and contexts, thus providing rich, contextualized data. The theoretical frameworks guiding the study were the SAMR Model and the Refined Consensus Model of Pedagogical Content Knowledge. The SAMR Model was selected to assess and guide the levels of technology integration, from substitution to redefinition, while the Refined Consensus Model of PCK was used to examine how teachers' content knowledge, pedagogical knowledge, and technological knowledge intersected to influence their teaching practices. A collaborative approach was used throughout the research process, involving teachers in the development and refinement of the practical framework, ensuring that the recommendations were grounded in real-world teaching experiences and responsive to the teachers' needs and insights.

The study aimed to find out:

1. The extent in which the teachers integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners.

2. Steps that teachers can follow to integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners.

5.1.1 The extent on which the teachers integrated smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners.

The teachers demonstrated a significant degree of integration of smartboard affordances with pedagogy, particularly in enhancing visual learning and engagement. They consistently utilized PowerPoint presentations, annotation tools, and interactive activities to deliver content and assess understanding. The use of visual aids, such as diagrams, images, and videos, was a common practice across all participants, indicating a strong emphasis on visual learning. Teachers used the annotation feature to explain complex processes and provide real-time feedback, showcasing their ability to adapt their teaching to learners' needs. Interactive activities like quizzes and games were also frequently employed to reinforce concepts and promote active participation.

However, there were some limitations. Teachers often struggled to fully utilize interactive affordances like polls and virtual labs, indicating a need training. Time constraints sometimes led to the exclusion of kinaesthetic activities, limiting the ability to cater to all learning styles. Furthermore, while teachers used the smartboard for visual and auditory learning, opportunities to incorporate more hands-on, collaborative activities were sometimes missed. The reliance on PowerPoint and annotation, while effective, sometimes overshadowed the integration of learning management systems for enhanced collaboration and progress tracking. Overall, the teachers demonstrated a strong commitment to integrating smartboard affordances, but there is room for improvement in fully leveraging the technology's interactive capabilities and addressing diverse learning needs.

5.1.2 Steps that teachers can follow to integrate smartboard affordances with pedagogy when teaching photosynthesis to grade 11 life sciences learners.

To integrate smartboard affordances into teaching grade 11 photosynthesis, findings from the collaborative planning and teaching processes showed that teachers can follow a structured sequence, beginning with a deep dive into the content knowledge itself. The content knowledge stands as the cornerstone, particularly when leveraging smartboard affordances. This domain represents the teacher's deep understanding of the subject matter itself, in this case, photosynthesis (Redmond and Lock, 2019). They can start by analysing the photosynthesis curriculum, pinpointing core concepts like the light and dark reactions, the role of chloroplasts, and the energy transformations involved. This initial step is paramount, as a deep understanding of content knowledge will serve as the foundation for all pedagogical decisions.

Teachers must know if the content involves how energy flows through ecosystems (ecology), how organisms utilize that energy (physiology), the chemical reactions involved (biochemistry), or the fundamental laws of energy transfer (energetics). This understanding extends beyond simple definitions; it requires teachers to grasp the interconnectedness of these fields and how they contribute to the overarching concept of photosynthesis. For instance, knowing the biochemical pathways of the light phase and dark phase is crucial for explaining how carbon dioxide is converted into glucose, but without understanding the ecological context of how plants use this glucose for growth and survival, the learning experience remains incomplete.

Teachers can then dissect the nature of this content, asking themselves: "Does this concept lend itself to visual representation? Is it best explained through a process-oriented animation? Or does it require comparative analysis?" For example, if the concept revolves around the intricate steps of the light dependent phase and light independent phase, they can recognize that a visual animation or interactive diagram on the smartboard will be more useful than a simple text-based explanation, allowing for a dynamic exploration of the biochemical ways. This decision-making process is significantly informed by the teacher's personal PCK, which represents their unique blend of content and pedagogical knowledge developed through experience and reflection. Furthermore, the teacher needs to consider collective PCK, which encompasses the shared knowledge and best practices within the teaching community, influencing how photosynthesis is typically taught and understood. This could include collaborative lesson planning amongst teachers from the same school or neighbouring schools.

Building upon this content-centric foundation, teachers can then consider the pedagogical strategies that will best illuminate the chosen concepts. Pedagogical knowledge encompasses the broad principles and strategies of teaching and learning, including instructional techniques, classroom management, and assessment methods (Sonmark et al.,2017). It is about how to facilitate learning, regardless of the specific subject matter (Sonmark et al.,2017). Recognizing that grade 11 learners possess diverse learning styles; teachers can plan to employ a variety of instructional methods. For instance, if the content involves labelling the chloroplast's organelles, they can utilize interactive diagrams on the smartboard, allowing learners to drag and drop labels, reinforcing their understanding through active participation. This aligns with the augmentation level of the SAMR model, enhancing traditional teaching without fundamentally changing it.

If the aim is to explain the process of photosynthesis, they can incorporate animated videos that visually depict the energy transfer and chemical reactions, making abstract concepts more tangible. When comparing the light and dark phases, side-by-side diagrams on the smartboard can facilitate a clear visual comparison, highlighting the key differences and similarities. For the requirements of photosynthesis, teachers can utilize interactive diagrams that display the necessary components, such as light, water, and carbon dioxide. This pedagogical reasoning stems from an understanding that visual aids are crucial for comprehending complex biological processes. Teachers can ensure that the learning experience is engaging by selecting pedagogical strategies that align with the nature of the content. Simultaneously, teachers can reflect on their knowledge of the learners which involves recognizing the diverse needs, backgrounds, and learning styles of individual learners, enabling teachers to tailor instruction for optimal engagement and comprehension (Roy and Bairagya, 2019). They can consider the diverse learning needs of their learners, anticipate potential misconceptions and tailor their instruction accordingly. For example, if they know that some learners struggle with abstract concepts, they can incorporate real-world examples and analogies to make photosynthesis more relatable.

They can also consider the knowledge of the context which refers to understanding the specific learning environment, including available resources, school culture, and the broader community influences that may impact the teaching process (Mishra, 2019). If they have access to a well-equipped science lab, they can plan hands-on activities that complement the smartboard affordances, reinforcing learning through practical application. Finally, they can utilize the smartboard affordances to foster collaborative learning, encouraging learners to work together and share their understanding. The teacher's ability to adapt these strategies in real-time, based on learner responses and engagement, will reflect their enacted PCK, the dynamic application of their knowledge in the classroom. Through this systematic approach, teachers can leverage smartboard affordances to create a rich and engaging learning experience that deepens grade 11 learners' understanding of photosynthesis.

Figure 27: A summary of a sequence that teachers can follow to integrate smartboard affordances with pedagogy to teach photosynthesis.

Figure 27 shows a five-step process for effectively integrating smartboard technology into a Grade 11 photosynthesis lesson, starting with Deep Content Knowledge Acquisition and ending with Continuous Reflection and Refinement. This figure is important because it provides a structured and deliberate framework for teachers to move beyond basic technology use and strategically integrate smartboard affordances to enhance pedagogical practice.

5.2 Challenges faced by teachers when integrating smartboard with pedagogy.

The use of smartboard affordances for teaching grade 11 learners' photosynthesis was notably disadvantaged by inconsistent electricity supply. In School 3, a planned observation was completely stopped by a widespread blackout, forcing a schedule change. This event highlighted a key weakness of smartboard-based instruction, its dependence on reliable electricity. Aside from electricity issues, technical problems also affected the usage smartboard affordances. In School 3, the touchscreen's responsiveness was erratic, requiring repeated touches to function. This technical glitch interrupted lesson flow and led to teacher and learner frustration. This is the same challenged that is highlighted in study conducted by Pourciau (2014) where the interviewed teachers mentioned that they had faced technical difficulties when using smartboard affordances like when the pens would not write or when the smartboard itself did not work. They highlighted how they did not know how to deal with those challenges besides waiting for the school system to fix those problems.

Another challenge revolved around the balance between visual and interactive learning. While teachers excelled at using the smartboard for visual representation through diagrams, images, and videos, they sometimes missed opportunities to incorporate more hands-on and collaborative activities. The reliance on PowerPoint and annotation, though effective, occasionally overshadowed the integration of learning management systems for enhanced collaboration and progress tracking. Finally, despite utilizing the annotation affordances to explain complex processes, teachers sometimes struggled to fully integrate digital resources like virtual labs and online simulations, limiting the depth of interactive engagement. This indicated a gap in their ability to fully utilize the internet connectivity affordances of the smartboard for enhanced learning experiences.

5.3 Implication of the study

This study reveals significant implications for the integration of smartboard affordances in Life Sciences education, particularly concerning the teaching of complex topics like photosynthesis. Firstly, the research underscores the necessity of moving beyond mere substitution as per the SAMR model in smartboard usage. Simply projecting PowerPoint presentations, while helpful, does not fully leverage the smartboard affordances potential. The findings suggest that effective integration requires teachers to progress through augmentation, modification, and ideally, redefinition. For instance, utilizing annotation tools for real-time explanations and interactive activities like virtual labs moves towards modification, where smartboard enhances the learning experience. Redefinition, however, would involve creating entirely new learning experiences that were previously impossible, such as collaborative virtual experiments facilitated by the smartboard affordances.

Secondly, the study highlights the critical role of PCK, specifically as framed by the Refined Consensus Model of PCK. The teachers' ability to integrate smartboard affordances was directly linked to their understanding of how these tools could enhance content delivery and learner engagement. Effective integration required teachers to consider the intersection of content knowledge (photosynthesis), pedagogical knowledge (teaching strategies), technological knowledge (smartboard affordances), and learner knowledge (understanding learners' misconceptions). The study implies that professional development programs should focus on enhancing teachers' PCK by providing opportunities to practice integrating smartboard affordances into their teaching in meaningful ways. This includes fostering a deeper understanding of how smartboard affordances can address specific learning challenges related to photosynthesis, such as visualizing microscopic processes.

Furthermore, the study suggests that the successful integration of smartboards requires a systemic approach. Schools need to provide not only the smartboard but also the necessary support, including consistent electricity supply, technical maintenance, and ongoing professional development. The findings emphasize that smartboard affordances integration is not just about having the tools but also about creating an environment that supports their effective use. This includes addressing infrastructural limitations and providing teachers with the time and resources they need to experiment with and refine their smartboard affordances integration practices.

5.4 Limitations of the study.

Several limitations were considered when interpreting the findings of this study. A significant weakness arose from the researcher's dual role as both an observer and a participant. The debriefing process, where the researcher, as a participant observer, confirmed observations with the three participating teachers, could have been susceptible to confirmation bias. The researcher's presence and her prior knowledge of the research questions may have subtly influenced the three participating teachers' responses during the debriefing, leading them to confirm interpretations that aligned with the researcher's expectations rather than their true intentions. To mitigate this, an external, neutral party could have been used to facilitate the debriefing sessions. This would have helped ensure that the teachers' feedback was independent of the researcher's influence. Additionally, the researcher could have employed a more structured protocol for debriefing, using open-ended, non-leading questions to encourage teachers to provide their own interpretations without prompting.

The researcher only taught one lesson at each of the three participating schools. While this provided some firsthand experience, it was not sufficient to fully grasp the complexities of each school's unique context, culture, and learner dynamics. This limited exposure could have led to misinterpretations of the observed pedagogical practices. To avoid this, the researcher could have spent a more extended period in each school, perhaps teaching more than one lesson over several days. This extended commitment would have allowed for a deeper understanding of the context, enabling a more nuanced and accurate interpretation of the teachers' actions and decisions.

The study's process of sharing transcripts and video recordings with participants for validation could have created an information overload. Participants, particularly busy teachers, might have found it burdensome to review lengthy and detailed documents or videos, potentially leading to superficial confirmation rather than a thorough and critical review. This could have weakened the member checking process. To address this, the researcher could have provided a concise summary of the key themes and findings for participants to review first, with the option to access the full transcripts or videos for more detailed verification. This approach would have respected the participants' time while still ensuring the core findings were validated.

The researcher's creation of narratives from audio and video recordings introduced potential for subjective interpretation. The process of selecting and framing specific parts of the recordings to form a coherent narrative could have inadvertently emphasized certain aspects while downplaying others, potentially misrepresenting the participants' experiences or perspectives. To enhance the rigor of this process, the researcher could have adopted a collaborative narrative-building approach. This would have involved co-creating the narratives with the participants, allowing them to provide feedback and co-author the final versions. This shared ownership would have ensured that the narratives were not only accurate but also resonated deeply with the participants lived experiences.

5.5 Recommendations of the study/ Suggestion for future research

Future research can use this model to study how smartboards can be used in teaching complex science topics. A good place to do this research would be in a secondary school life sciences classroom where Grade 11 learners are learning about photosynthesis. This setting is perfect for researchers to see how the model (depicted at section 5.1.2) works in a real school and to find out if it helps learners learn better. Future studies can re-test the proposed model, which goes from learning a subject deeply to always thinking about and improving your teaching. The main goal would be to look at how teachers can integrate smartboard affordances with pedagogical strategies for teaching Grade 11 photosynthesis. Researchers could use this model as a framework to design and implement teaching intervention. They could then collect data on how the strategic use of smartboards affordances influences learners' understanding of concepts like the light-dependent and light-independent reactions and the overall process of energy conversion. The model provides a structured way to analyse the relationship between technology, teaching methods, and learner comprehension in this specialized domain.

Expanding the study to a larger group of participants (teachers and learners) would be essential for increasing the statistical power and generalizability of the findings. Instead of a single classroom or a small group of learners, future research could be conducted across more than three schools. This larger sample size would help to confirm whether the observed effects are consistent across different educational settings and learner demographics. Researchers can produce more robust and reliable evidence regarding the efficacy of the proposed model, lending more credibility to its potential for widespread application in science education by replicating the study with a broader population.

5.6 Conclusion: Final statement on the significant of the study

This study provides valuable insights into the complex interplay between smartboard integration and pedagogical content knowledge in the Life Sciences classroom. The study suggests a framework for analysing and understanding teacher practices by employing the Refined Consensus Model of PCK and the SAMR model. The findings highlight the importance of moving beyond basic substitution of smartboard and embracing higher levels of integration to enhance learning experiences. Furthermore, the study underscores the need for ongoing professional development to address potential gaps in teachers' PCK, particularly in areas like knowledge of learners and curricular knowledge. Ultimately, this research contributes to a deeper understanding of how smartboard affordances can be integrated to improve teaching and learning in the digital age, providing practical guidance for educators seeking to enhance their pedagogical practices. The study also shows the importance of using both the SAMR model, and the PCK model together, to gain a more complete picture of the teaching process.

6. References

Abdullah, A. H., Soh, H. M., Mokhtar, M., Hamzah, M. H., Ashari, Z. M., Ali, D. F., ... & Abd Rahman, S. N. S. (2020). Does the use of smart board increase students' higher order thinking skills (HOTS)?. *Ieee Access*, *9*, 1833-1854.

Abdulrahaman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. V., Imam-Fulani, Y.O., Fahm, A.O., & Azeez, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon*, *6*(11).

Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi structured interviews. *Journal of the american college of clinical pharmacy*, *4*(10), 1358-1367.

Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi structured interviews. Journal of the american college of clinical pharmacy, 4(10), 1358-1367.

Ahmed, M. A., & Lawal , K. B. (2020). Effects of learning together on senior school students' achievement in photosynthesis and students' gender in Offa, Nigeria. Journal of Arts & Social Sciences, 1-10.

Ahmed, S. K. (2024). The pillars of trustworthiness in qualitative research. *Journal of Medicine, Surgery, and Public Health*, *2*, 100051.

Akar, H. (2020). The Effect of Smart Board Use on Academic Achievement: A Meta-Analytical and Thematic Study. 8. 261-273. 10.46328/ijemst.v8i3.908.

Alharahsheh, H. H., & Pius, A. (2020). A review of key paradigms: Positivism VS interpretivism. Global Academic Journal of Humanities and Social Sciences, 2(3), 39 43.

Alivi, J. S. (2019). A review of tpack and samr models: how should language teachers adopt technology?. Journal of English for Academic and Specific Purposes (JEASP), 2(2), 1 11.

Al-Kahlan, T. B. S., & Khasawneh, M. A. S. (2023). Advantages of using the Interactive Whiteboard as an Educational Tool from the Point of View of Middle School Teachers in Asir Region. Migration Letters, 20(S1), 889-900.

Almualimah, V. A., Fadly, W., & Tumennasan, M. (2024). Understanding the Solution Making Ability of Senior High School Students in Solving Photosynthesis Problems. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 1586-1598.

Alonso-García, S., Aznar-Díaz, I., Caceres-Reche, M. P., Trujillo-Torres, J. M., & Romero Rodriguez, J. M. (2019). Systematic review of good teaching practices with ICT in Spanish Higher Education. Trends and Challenges for Sustainability. Sustainability, 11(24), 7150.

Alshumaimeri, Y. (2023). Understanding context: An essential factor for educational change success. Contemporary Educational Researches Journal. 13. 11-19. 10.18844/cerj.v13i1.8457.

Andreae, E. (2021). 4 Filming Research: Video Recordings. Filming, Researching, Annotating.

Appova, A., & Taylor, C. E. (2020). Providing opportunities to develop prospective teachers' pedagogical content knowledge. The Mathematics Enthusiast, 17(2), 673-724.

Aristyasari, N. E., & Yuliani, Y. (2021). Misconception Profile on Photosynthesis by Using Four-Tier Diagnostic Test on Twelve Grade Students of Senior High School. Berkala Ilmiah Pendidikan Biologi (BioEdu), 10(3), 501-509.

Bajracharya, J. (2021). Technology Integration Models and Frameworks in Teaching and Training. Journal of Training and Development, 6.

Bakare, J., Ariyo, S. O., & Ojo, S. A. (2021). Constraints and Performance Gap Analysis (CPGA) of Lecturers in Utilizing Smart Boards for Improving Students' Engagement, Motivation and Learning Outcomes (SEMLOs). *International Journal of Research in Education and Science*, *7*(3), 681-714.

Baslam, M., Mitsui, T., Hodges, M., Priesack, E., Herritt, M. T., Aranjuelo, I., & Sanz-Sáez, Á. (2020). Photosynthesis in a changing global climate: Scaling up and scaling down in crops. Frontiers in Plant Science, 11, 882.

Behling, F., Förtsch, C., & Neuhaus, B. J. (2022). The refined consensus model of pedagogical content knowledge (PCK): Detecting filters between the realms of PCK. Education Sciences, 12(9), 592.

Belay, M. T. (2020). Integration Of Information And Communication Technology In Teaching And Learning Of Biology In Secondary Schools In Southern Region, Eritrea (Doctoral dissertation, KENYATTA UNIVERSITY).

Belouahem, Z. (2020). Rote Vs Meaningful Learning in EFL Classes: Perspectives and Beliefs.

Bernát, M., Pavlovkin, J., Džmura, J., Žáčok, Ľ., Bernátová, R., Petráš, J., Rudolf, L., & Sepešiová, M. (2020). The effectiveness of interactive whiteboard using NIESVE system for electrical engineering students. Journal of Technical Education and Training, 12(1 Special Issue), 204–217. https://doi.org/10.30880/jtet.2020.12.01.022.

Bernátová, R., Bernát, M., Poráčová, J., & Nagy, M. (2020). Teaching of the thematic unit photosynthesis in the natural sciences with didactics for teacher training programmers in primary education with the support of the interactive whiteboard. *Journal of Science Education*, *21*(2).

Bizimana, E., Mutangana, D., & Mwesigye, A. (2022). Effects of School Location on Students' Achievement in Photosynthesis Based on Concept Mapping Instructional Strategy. *Eurasian Journal of Science and Environmental Education*, *2*(1), 1-10.

Bizimana, E., Mutangana, D., & Mwesigye, A. (2022). Fostering Students' Retention in Photosynthesis Using Concept Mapping and Cooperative Mastery Learning Instructional Strategies. European Journal

Bolaji, H. O., & Adeoye, M. A. (2022). Accessibility, Usability, and Readiness Towards ICT Tools for Monitoring Educational Practice in Secondary Schools in Ilorin Metropolis. Indonesian Journal of Multidiciplinary Research, 2(2), 257-264.

Bolaji, H. O., & Jimoh, H. A. (2023). Usability and utilization of ICT among educational administrators in secondary students in public school. *Indonesian Journal of Educational Research and Technology*, *3*(2), 97-104.

Botha, H., Coetzee, C., & Zweers, L. (2023). Teaching measurement: The role of mathematics teachers' enacted PCK on gain in learner outcomes. Infinity Journal, 12(2), 307-322.

Bressanelli, G., Perona, M., & Saccani, N. (2019). Challenges in supply chain redesign for the Circular Economy: a literature review and a multiple case study. *International Journal of Production Research*, *57*(23), 7395-7422.

Busetto, L., Wick, W., & Gumbinger, C. (2020). How to use and assess qualitative research methods. *Neurological Research and practice*, *2*(1), 14.

Carlson, J., & Daehler, K. (2019). The Refined Consensus Model of Pedagogical Content Knowledge in Science Education. 10.1007/978-981-13-5898-2_2.

Champa, R. A., Rochsantiningsih, D., & Kristiana, D. (2021). TEACHERS'CHALLENGES TO INTEGRATE ICT IN EFL TEACHING AND LEARNING ACTIVITIES. In English Language and Literature International Conference (ELLiC) Proceedings (Vol. 3, pp. 135-145).

Chand, G. B. (2024). Narrative Inquiry: A Critical Examination of Its Theoretical Foundations and Methodological Applications. Far Western Review, 2(1), 135-152.

Das, K. (2019). The role and impact of ICT in improving the quality of education: An overview. International Journal of Innovative Studies in Sociology and Humanities, 4(6), 97-103.

Daudi, Y., & Nzilano, J. L. (2019). ICT integration in teaching and learning: perceptions and practices of secondary school students in Tanzania. University of Dar es Salaam Library Journal, 14(2), 38-52.

Demirbilek, M. (2022). Software and Hardware Problems That Teachers Experience when Using Smart Board. International Society for Technology, Education, and Science.

Department of Basic Education. (2011). Curriculum and Assessment Policy Statement (CAPS): Mathematics Grade 10-12. Pretoria: Department of Basic Education.

Dlamini, R. (2022). Factors constraining teacher integration of ICT in Gauteng schools.17.2843.

Dudaitė, J., & Prakapas, R. (2019). Influence of use of Activinspire interactive whiteboards in classroom on students' learning. Digital Education Review, (35), 299-308.

Eriksson, A., Gericke, N., & Olsson, D. (2024). Expanding and Enhancing the Notion of Photosynthesis Education in an Educational Design Research Study. In *ERIDOB2024, 14th Conference of European Researchers in Didactics of Biology, Lyon, France, July 1-July 5* (pp. 18-19).

Fagan, D. (2020). Using ICTs as a pedagogical resource to facilitate epistemological access in science with teacher education students (Doctoral dissertation, UWC).

Farhang, A. P. Q., Hashemi, A. P. S. S. A., & Ghorianfar, A. P. S. M. (2023). Lesson plan and its importance in teaching process. *International Journal of Current Science Research and Review*, *6*(08), 5901-5913.

Fatmawati, B., & Rustaman, N. Y. (2020). The study of inquiry ability in the photosynthesis concept. Jurnal Pendidikan IPA Indonesia, 9(4), 583-589.

Fermani, M., & Georgiou, M. (2023). TEACHING PHOTOSYNTHESIS USING AN INQUIRY-BASED APPROACH VIA A DIGITAL EDUCATIONAL PLATFORM TO PROMOTE STUDENTS'UNDERSTANDING. *European Journal of Education Studies*, *10*(12).

Ferreira, J. M., Soini, T., Kupiainen, R., & Salum, A. C. (2019). What is learning for secondary school students? students' perceptions examined in brazil and finland. *Social Psychology of Education, 22*(2), 447-470. https://doi.org/10.1007/s11218-019-09479-5

Filgona, J & John, S & Gwany, D. (2020). TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE AND STUDENTS' ACADEMIC ACHIEVEMENT: A THEORETICAL OVERVIEW. 14. 14-44.

Gillespie, R. (2022). SAMR: The Power of a Useful Technology Integration Model. Technology and the Curriculum: Summer 2022.

Göçen, A., Eral, S. H., & Bücük, M. H. (2020). Teacher perceptions of a 21st century classroom. International Journal of Contemporary Educational Research, 7(1), 85-98.

Gumede, E. N., & Mavuru, L. (2025). Teachers' Understandings and Practices of Using Smartboards as Digital Tools to Teach Grade 12 Life Sciences Genetics. *International Journal of Learning, Teaching and Educational Research*, *24*(5), 323-338.

Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study.

Hendawi, M., & Nosair, M. R. (2020). The Efficiency of Using the Interactive Smartboard in Social Studies to Increase Students' Achievement and Tendency Toward the Subject Matter in the State of Qatar. *International Journal of Learning, Teaching and Educational Research*, *19*(3), 1-19.

Hossain, M. A., Polash, M. A. S., Karim, M. M., Juthee, S. A., & Sakil, M. A. (2022). Photosynthesis: Fundamentals and advances. *Int. J. Biosci*, *21*, 443-463.

Hussein, H. A., Ahmed, A. M. H., Shawkat, S. A., & Kamil, R. A. (2022, November). The effect of using smart board technology on the educational process in the colleges of education in terms of features and challenges. In *AIP Conference Proceedings* (Vol. 2394, No. 1). AIP Publishing.

Ifinedo, E., Rikala, J., & Hämäläinen, T. (2020). Factors affecting Nigerian teacher educators' technology integration: Considering characteristics, knowledge constructs, ICT practices and beliefs. *Computers & education*, *146*, 103760.

Irmer, M., Traub, D., Böhm, M., Förtsch, C., & Neuhaus, B. J. (2023). Using video-based simulations to foster pPCK/ePCK—new thoughts on the refined consensus model of PCK. *Education Sciences*, *13*(3), 261.

Issa, R. A. S. A. (2020). *Teachers' and students' views on using smart boards in teaching and learning english as a foreign* (Doctoral dissertation, Doctoral dissertation. Middle East University).

Jackson, R. L., Drummond, D. K., & Camara, S. (2007). What is qualitative research?. Qualitative research reports in communication, 8(1), 21-28.

Jammeh, A. L., Karegeya, C., & Ladage, S. (2022). The Smartboard in Chemistry Classrooms: What is Its Effect on Chemistry Teaching and Learning in Selected Topics in Grade 11?. International Journal of Learning, Teaching and Educational Research, 21(9), 217-231.

Jančaříková, K., & Jančařík, A. (2022). How to Teach Photosynthesis? A Review of Academic Research. Sustainability, 14(20), 13529.

Jayanti, P. (2019). Comparative study: Misconceptions on photosynthesis and respiration concepts from past to the present. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *9*(1), 1750-1755.

Kapur, R. (2020). Understanding the Meaning and Significance of Pedagogy.

Karakaya, F., Yılmaz, M. E. H. M. E. T., & Elvan, E. L. V. A. N. (2021). Examination of Pre Service Science Teachers Conceptual Perceptions and Misconceptions about Photosynthesis. *Pedagogical Research*, *6*(4).

Karthigesu, K., & Mohamad, M. (2020). Primary school teachers' perceptions on the integration of interactive whiteboard (IWB) during reading instructions. *International Journal of Academic Research in Business and Social Sciences*, *10*(2), 722-741.

Kgosi, M. K., Makgato, M., & Skosana, N. M. (2023). Teachers' views on the application of educational technologies in the classroom: a case of selected Tshwane West secondary schools in Gauteng. Journal of Curriculum Studies Research, 5(2), 151166.https://doi.org/10.46303/jcsr.2023.23

Khosa, C., & Molotsi, A. R. (2020). Teachers' perspectives on the use of smart boards in teaching business studies in the Tshwane West District. In Proceedings of the South Africa International Conference on Education (SAICEd) (pp. 297-306).

Kılıç, A. (2024). Examining Pre-Service Science Teachers' Personal and Enacted Pedagogical Content Knowledge About Seasons. Journal of Theoretical Educational Science, 17(1), 100-121.

Korkmaz, O., & Cakil, I. (2013). Teachers' difficulties about using smart boards. *Procedia Social and Behavioral Sciences*, *83*, 595-599.

Kühl, T., & Wohninsland, P. (2022). Learning with the interactive whiteboard in the classroom: Its impact on vocabulary acquisition, motivation and the role of foreign language anxiety. *Education and Information Technologies*, *27*(7), 10387-10404.

Lee, Y., Capraro, M. M., & Viruru, R. (2018). The factors motivating students' STEM career aspirations: Personal and societal contexts. *International Journal of Innovation in Science and Mathematics Education*, *26*(5).

Li, M. (2022). An Exploration On Concept Teaching Knowledge Of Biology Teachers In Lower-Secondary Schools. Journal of Baltic Science Education, 21(1), 121-139.

Lim, H.L., & Poo, Y.P. (2021). A Diagnosis of Students' Misconceptions of Photosynthesis and Plant Respiration. Asia Pacific Journal of Educators and Education.

Maher, C., Hadfield, M., Hutchings, M., & de Eyto, A. (2018). Ensuring Rigor in Qualitative Data Analysis: A Design Research Approach to Coding Combining NVivo With Traditional Material Methods. *International Journal of Qualitative Methods*, *17*(1). https://doi.org/10.1177/1609406918786362

Manullang, T. I. B., Nandiyanto, A. B. D., Suryadi, A., Rochyadi, E. N. D. A. N. G., Haerudin, D. I. N. G. D. I. N. G., Muspita, R. I. L. A., ... & Manullang, L. S. (2021). Improving students with intellectual disabilities science process skills through photosynthesis experiment in enhancing climate change awareness. *Journal of Engineering Science and Technology*, *16*(3), 2368-2377.

Mapumulo, N. (2023). Teachers' understanding and experiences on the intergration of Information and Communication Technology (ICT) in teaching and learning in Natural Sciences and Technology (Doctoral dissertation, University of Johannesburg).

Maru, M. G., Pikirang, C. C., Ratu, D. M., & Tuna, J. R. (2021). The Integration of ICT in ELT Practices: The Study on Teachers' Perspective in New Normal Era. Int. J. Interact. Mob. Technol., 15(22), 44-67.

Mashiteng, E. (2020). *The Experiences of Mathematics Teachers in the Use of Smartboards* (Order No. 28278549). Available from ProQuest Dissertations & Theses Global. (2505376365). https://www.proquest.com/dissertations-theses/experiences mathematics-teachers-use-smartboards/docview/2505376365/se-2

Mekonen, D., & Kelkay, A. D. (2023). Inquiry-based instructional strategies for effective conceptualization of photosynthesis: The case of elementary school. *Cogent Education*, *10*(1), 2172927.

Mhlamvu-Zikhali, N. V. (2010). *Conceptual understanding of photosynthesis* (Doctoral dissertation).

Mihai, M. A. (2020). The use of interactive whiteboards in urban Gauteng classrooms.

Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. Journal of digital learning in teacher education, 35(2), 76-78.

Mkhanyiswa, Z. (2022). *Exploring alternative pedagogies for teaching grade 11 further education and training life sciences* (Doctoral dissertation, Cape Peninsula University of Technology).

Mlambo, S., Rambe, P., & Schlebusch, L. (2020). Effects of Gauteng province's educators' ICT self-efficacy on their pedagogical use of ICTS in classrooms. Heliyon, 6(4).

Mokoena, M.M., Simelane-Mnisi, S., & Mji, A. (2022). Challenges and Solutions for Teachers' Use of Interactive Whiteboards in High Schools. *Universal Journal of Educational Research*.

Momani, M., Alshaikhi, T. S., & Al-Inizi, T. H. (2016). The obstacles of using smart board in teaching English at Tabuk secondary schools. *Asian Journal of Educational Research*, *4*(3).

Mtshali, N. T. (2021). Grade 12 teachers' experiences in using interactive whiteboards when teaching Life Sciences. University of Johannesburg (South Africa).

Mun, S.H., Abdullah, A.H., Mokhtar, M., Ali, D.F., Jumaat, N.F., Ashari, Z.M., Samah, N.A., & Rahman, K.A. (2019). Active Learning Using Digital Smart Board to Enhance Primary School Students' Learning. Int. J. Interact. Mob. Technol., 13, 4-16.

Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: a literature review. International Journal of Humanities and Innovation (IJHI), 4(1), 1-4.

Nautiyal, R., & Dabral, P. (2023). Exploring Pre-service Teachers' Perspectives on TPACK: Technology, Pedagogical, and Content Knowledge. Journal of Mountain Research.

Ndlovu, P. P. (2021). *Life Sciences Teachers' Experience in the Use of Interactive Whiteboard (IWB) when Teaching Grade 10 Cell Division* (Order No. 28935491).

Ndwandwe, K. P., Ramaligela, S. M., & Mtshali, T. I. (2024). The effectiveness of smartboards in enhancing technology teachers' creativity. African Perspectives of Research in Teaching and Learning, 8(1), 1-9. https://www.proquest.com/scholarly journals/effectiveness-smartboards-enhancing-technology/docview/2973459697/se-2

Nishanthi,, R., & Ravindran, V. (2020). Smart Board Learning-A Review. International Journal of Pharmaceutical Research (09752366), 12(2).

Opara, E., Mfon-Ette Theresa, A., & Aduke, T. C. (2023). ChatGPT for teaching, learning and research: Prospects and challenges. Opara Emmanuel Chinonso, Adalikwu Mfon-Ette Theresa, Tolorunleke Caroline Aduke (2023). ChatGPT for Teaching, Learning and Research: Prospects and Challenges. Glob Acad J Humanit Soc Sci, 5.

Orhani, S. (2023). The Contribution of the Smart Board to the Improvement of Learning Results in the Subject of Mathematics.

Paidican, M. A., & Arredondo, P. A. (2022). The technological-pedagogical knowledge for in service teachers in primary education: A systematic literature review. Contemporary educational technology, 14(3).

Palanisamy, C., & Sivakumar, G. (2020). Effectiveness of Science Teaching through Smartboard Technology among Primary Teacher Training Students of Nagapattinam District. 2278-8719.

Pamungkas, M.S., Saputro, S., & Mulyani, S. (2019). Misconceptions on Photosynthesis and Plant Respiration Topics Based on Thinking Styles. Journal of Physics: Conference Series, 1241.

Pervin, N., & Mokhtar, M. (2022). The Interpretivist research paradigm: A subjective notion of a social context. International Journal of Academic Research in Progressive Education and Development, 11(2), 419-428.

Petruţa, G. P. (2016). Methodological issues concerning the use of smart board within the biology lessons. European Proceedings of Social and Behavioural Sciences.

Pourciau, E. A. L. (2014). *Teaching and learning with smart board technology in middle school classrooms* (Doctoral dissertation, Walden University).

Qader, M. A. (2021). The Role of Interactive Whiteboards for Enhancing Teaching and Learning in Higher Education. Indonesian Journal of Curriculum and Educational Technology Studies, 9(1), 19-24.

Radhi, R. I., & Sabri, D. A. (2021). The Effect of the SAMR Model on Acquiring Teaching Skills for Students of Colleges of Education in the Subject of Teaching Applications. International Journal of Early Childhood Special Education, 13(2).

Rajagopalan, I. (2019). Concept of Teaching. Shanlax International Journal of Education, 7(2), 5-8.

Ramorola, M. (2014). Information and Communication Technology Integration: Where to Start, Infrastructure or Capacity Building?. Procedia - Social and Behavioral Sciences. 116. 3649-3658. 10.1016/j.sbspro.2014.01.818.

Razak, N., Ab Jalil, H., & Ismail, I. (2019). Challenges in ICT integration among Malaysian public primary education teachers: The roles of leaders and stakeholders. International Journal of Emerging Technologies in Learning (iJET), 14(24), 184-205.

Redmond, P., & Lock, J. (2019). Secondary pre-service teachers' perceptions of technological pedagogical content knowledge (TPACK): What do they really think?. Australasian Journal of Educational Technology, 35(3).

Redmond, P., & Lock, J. (2019). Secondary pre-service teachers' perceptions of technological pedagogical content knowledge (TPACK): What do they really think?. Australasian Journal of Educational Technology, 35(3).

Rinekso, A. B., & Lesagia, O. (2020). EFL INSTRUCTORS BELIEFS ABOUT THE IMPLEMENTATION OF SMARTBOARD IN LANGUAGE TEACHING PRACTICES. *LLT Journal: A Journal on Language and Language Teaching*, *23*(1), 144-156.

Rosales, L. (2021). Technology Integration: Implication for Teachers 'Professional Development. In The Southeast Asian Conference on Education 2021 Official Conference Proceedings.

Roy, S., & Bairagya, S. (2019). Conceptualisation of Pedagogical Content Knowledge (PCK) of science from Shulman's notion to Refined Consensus Model (RCM): A journey. Education India Journal: A Quarterly Refereed Journal of Dialogues on Education, 8(2), 10-53.

Roy, S., & Bairagya, S. (2019). Conceptualisation of Pedagogical Content Knowledge (PCK) of science from Shulman's notion to Refined Consensus Model (RCM): A journey. Education India Journal: A Quarterly Refereed Journal of Dialogues on Education, 8(2), 10-53.

Ruslin, R., Mashuri, S., Rasak, M. S. A., Alhabsyi, F., & Syam, H. (2022). Semi-structured Interview: A methodological reflection on the development of a qualitative research instrument in educational studies. IOSR Journal of Research & Method in Education (IOSR-JRME), 12(1), 22-29.

Ruzaman, N. (2020). Inquiry-based education: Innovation in participatory inquiry paradigm. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(10), 4-15.

Saka, A. (2019). Development of Preservice Biology Teachers' Skills in the Causal Process Concerning Photosynthesis. Journal of Education and Training Studies, 7(4), 51-62.

Salgado, E. (2024). Exploring Pre-Service Elementary Teachers' After Student-Teaching Content Knowledge and Teaching Knowledge of Fraction Operations (Order No. 31481685). Available from ProQuest Dissertations & Theses Global. (3077713888). https://www.proquest.com/dissertations-theses/exploring-pre-service-elementary teachers-after/docview/3077713888/se-2

Samsonova, O. (2020). Interactive Whiteboards in Elementary Schools. New Horizons in Education and Social Studies, 1, 98-108.

Sarkar, M., Gutierrez-Bucheli, L., Yip, S. Y., Lazarus, M., Wright, C., White, P. J., ... & Berry, A. (2024). Pedagogical content knowledge (PCK) in higher education: A systematic scoping review. *Teaching and Teacher Education*, *144*, 104608.

Sarma, D.J. (2024). Use of Online Resources for Teaching Learning Process in NEP. *INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS*.

Shah, R. K., & Campus, S. (2021). Conceptualizing and defining pedagogy. *IOSR journal of research & method in education*, *11*(1), 6-29.

Shah, S. S. (2022). Teaching and learning with technology: Effectiveness of ICT integration in schools. Indonesian Journal of Educational Research and Technology, 2(2), 133-140.

Shin, S. Y. S. S. Y., & Miller, S. M. S. (2022). A review of the participant observation method in journalism: Designing and reporting. Review of Communication Research, 10.

Singh, R. (2021). Impact of Information communication Technology In Online Classroom.

Skjott Linneberg, M., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative research journal*, *19*(3), 259-270.

Solomon, E., Martin, C., Martin, D. W., Berg, L. R. (2018). Biology. United States: Cengage Learning.

Sonmark, K., Révai, N., Gottschalk, F., Deligiannidi, K., & Burns, T. (2017). Understanding teachers' pedagogical knowledge: report on an international pilot study.

Stahl, N. A., & King, J. R. (2020). Expanding approaches for research: Understanding and using trustworthiness in qualitative research. *Journal of developmental education*, *44*(1), 26-28.

Suliman, M. M. A., & Ahmed, M. A. (2020). Investigating the Importance of Teaching and Learning with SMART Board/IWB Technology in Sudanese School.

Susanti, A., Hasanah, U., & Oktaviana, F. (2024). THE INTEGRATION OF SMART BOARD TECHNOLOGY IN LEARNING GRAMMAR: STUDENTS' PERSPECTIVES. Lingua. 20. 33-44. 10.34005/lingua.v20i1.3498.

Susanto, R., Rozali, Y. A., & Agustina, N. (2019). Development of pedagogical competency models for elementary school teachers: Pedagogical knowledge, reflective ability, emotional intelligence and instructional communication pattern. Universal Journal of Educational Research, 7(10), 2124-2132.

Tefo, R. M. (2021) The influence of smartboards on the teaching and learning of grade 12 physical science in Tshwane District, Gauteng, South Africa.

Telesphore, H. H., Celestin, N., & Philothere, N. (2023). From pedagogical content knowledge toward technological pedagogical content knowledge frameworks and their effectiveness in teaching mathematics: A mapping review. *F1000Research, 11*https://doi.org/10.12688/f1000research.125073.2

Terbeck, F. J. (2020). Defining suburbs: An evaluation and comparison of four methods. The Professional Geographer, 72(4), 586-597.

Toptaş, A. Ş. (2023). Views of foreign language teacher candidates on teaching profession and teaching practice. *Journal of Language Teaching and Learning*, *13*(2), 37-56.

Tsai, C. C. (2019). A study of Taiwanese elementary school English as a foreign language: Teachers' beliefs, advantages, and difficulties of using interactive whiteboards. *Asia Pacific Social Science Review*, *19*(4), 9.

Tsayang, G., Batane, T., & Majuta, A. (2020). The Impact of Interactive Smart Boards on Students' Learning in Secondary Schools in Botswana: A Students' Perspective. International Journal of Education and Development using Information and Communication Technology, 16(2), 22-39.

Ukkonen-Mikkola, T., & Ferreira, J.M. (2022). Video Recording as a Research Method for Investigating Children under Three Years of Age. Vzgoja in izobraževanje predšolskih otrok prvega starostnega obdobja.

Uqba, M. S. S., Hasaniyah, N., Al Anshory, A. M., & Rasyidah, N. (2024). The Role of Technology in Arabic Education: Smartboard Features and Challenges. *Ihtimam: Jurnal Pendidikan Bahasa Arab*, *7*(1), 72-86.

Vančugovienė, V., McMullen, J., Lehtinen, E., & Södervik, I. (2023). Exploring individual differences in photosynthesis and respiration knowledge in the context of green plants. *Journal of Biological Education*, 1-20.

Vithal, R., & Jansen, J. (2019) Designing your first research proposal [electronic resource]: a manual for beginning researchers. Cape Town: Juta. Second edition.

Wahyuni, S., Mujiyanto, J., Rukmini, D., & Fitriati, S. W. (2020). Teachers' technology integration into English instructions: SAMR model. In International Conference on Science and Education and Technology (ISET 2019) (pp. 546-550). Atlantis Press.

Warioba, M. M., Machumu, H., Kulunga, K., & Mtweve, L. (2022). Adoption of ICT as a pedagogical tool in community secondary schools in Tanzania: Possibilities and Constraints. *Education and Information Technologies*, 1-24.

Wisner, Ellen. (2022). Exploring the Complexities of Photosynthesis Through a Comic Strip. CourseSource. 9. 10.24918/cs.2022.33.

Woldeamanuel, Y. W., Abate, N. T., & Berhane, D. E. (2020). Effectiveness of Concept Mapping Based Teaching Methods on Grade Eight Students' Conceptual Understanding of Photosynthesis at Ewket Fana Primary School, Bahir Dar, Ethiopia. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(12).

Yadav, N. (2019). INTEGRETAION OF SMART BOARD IN TEACHING FOR B. COM STUDENTS IN GHAZIABAD. *Advance and Innovative Research*, 273.

Yalım, E. (2021). High school students' level of knowledge and attitudes towards the use of technology in biology classrooms (Doctoral dissertation, Bilkent Universitesi (Turkey).

APPENDIX 1: Wits Ethical Clearance Letter

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG | WSoE Wits School of Education

SCHOOL OF EDUCATION ETHICS COMMITTEE

CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER:** 2024ECE029M
PROJECT TITLE	Exploring the integration of smart board when teaching photosynthesis to grade 11 learners
INVESTIGATOR	RITHA MAZIBUKO
SCHOOL/DEPARTMENT OF INVESTIGATOR	WSoE
DATE CONSIDERED	10 June 2024
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	Minimal Risk
EXPIRY DATE	Date of submission of the Research Report
ISSUE DATE OF CERTIFICATE	15 July 2024
CHAIRPERSON	Dr. Lawan Abdulhamid

cc: Prof Eunice Nyamupa

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

I fully understand the conditions under which I am are authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

Mazibuko
Signature

Date 15 / July / 2024

27 St Andrews Road, Parktown, Johannesburg, 2193 | Pvt Bag 3, WITS, 2050 | T +27 11 717 3007 | www.wits.ac.za/education

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APPENDIX 2: Approval Letter from Gauteng Department of Education

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	04 July 2024
Validity of Research Approval:	08 February 2024– 30 September 2024 2024/187
Name of Researcher:	Mazibuko R
Address of Researcher:	7253 Tshepisong West
	Roodepoort
Telephone Number:	068 318 7838
Email address:	1637682@students.wits.ac.za
Research Topic:	Exploring the integration of smart board when teaching photosynthesis to grade 11 learners.
Name of University:	Wits
Type of qualification	Masters
Number and type of schools:	3 Secondary Schools
District/s/HO	Ekurhuleni South

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.
2. The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.
3. **Because of the relaxation of COVID 19 regulations researchers can collect data online, telephonically, physically access schools or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate.**
4. **The Researchers are advised to wear a mask at all times, Social distance at all times, Provide a vaccination certificate or negative COVID-19 test, not older than 72 hours, and Sanitise frequently.**
5. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.
6. A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.
7. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.
8. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.
9. Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.
10. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.
11. It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.
12. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
13. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.
14. On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.
15. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.
16. Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Mr David Bapela
CES: Education Research and Knowledge Management

DATE: 04/07/2024

2

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

APPENDIX 3: Information Letter for Principals

University of the Witwatersrand,
Wits school of education.
Paulina Hadebe
Tel: (27) 011 717 3162
Email: Paulina.Hadebe@wits.ac.za

15 May 2024

Dear Sir/Madam,

Re: Permission to conduct research at your school

My name is Ritha Mazibuko

I am studying for a master's degree in science education at the school of education at the University of the Witwatersrand. I am seeking permission to do research at your school.

I am conducting research on how teachers integrate smart board when teaching photosynthesis to grade 11 learners. The reason for this, despite its fundamental importance in biology, photosynthesis poses a significant learning challenge due to its multifaceted nature, encompassing elements of chemistry, physics, and various biological subdisciplines. This complexity often leads to rote memorization rather than a deep understanding of the interconnected processes. Smartboards have been shown to promote active learning and critical thinking in various subjects. However, simply incorporating them in classrooms does not guarantee effective learning. This research aims to investigate how teachers utilize smartboards to teach photosynthesis in Gauteng province, South Africa.

The research will entail collecting data from one grade 11 life sciences teacher. While teaching two lessons on the topic of photosynthesis.

I request permission to get access to the school's smart board, one grade 11 life sciences teacher and her learners. I will invite the grade 11 life sciences teacher together with her learners to participate in this study. If they agree, the teacher will be asked to be observed for one lesson; the teacher will be interviewed individually prior and after the first lesson and once after the second lesson. The researcher will teach the second lesson. The learners will only be observed during two lessons, they will not be interviewed. Furthermore, I will actively participate in lesson planning sessions with the teacher, gaining insights into her approaches to identify and document potential steps that teachers can follow when integrating smart boards with pedagogy during photosynthesis lessons. The data collection will take place on the school's premises after the teaching hours. The teacher's responses to interview questions will be audio recorded and the lessons will be video recorded.

Participants will be asked to give their written consent before the research begins. Their responses will be treated confidentially, and identities (their names and the name of the organization) will be anonymous unless otherwise expressly indicated. Individual privacy will be maintained in all published and written data resulting from the study. The results will be communicated in academic journals.

The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study and the participants will not be paid for this study.

All research data will be kept in a password encrypted google drive and will be destroyed three years after the study has been completed.

I therefore request permission in writing to conduct my research at your organization. The permission letter should be on your organization's headed paper, signed and dated, and specifically referring to myself by name and the title of my study.

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,
Ritha Mazibuko

Ritha Mazibuko
068 318 7838
1637682@students.wits.ac.za

Professor Eunice Nyamupangedengu
011 717 3752
eunice.nyamupangedengu@wits.ac.za

APPENDIX 4: Information Letter for Teachers and Consent Forms

PARTICIPANT INFORMATION LETTER FOR THE TEACHER

Good day,

My name is Ritha Mazibuko, I am a master's student at the University of the Witwatersrand, Johannesburg. My supervisor is Professor Eunice Nyamupangedengu. I am conducting a study on how teachers integrate smart board into their life sciences classrooms, particularly during grade 11 lessons on photosynthesis. The study title is 'Exploring the integration of smart board when teaching photosynthesis to grade 11 learners.'

As part of this research study, I humbly invite you to take part in three interview sessions, planning and delivering one photosynthesis lessons which I will observe, and I will teach the second lesson on photosynthesis. If you decide to take part, your participation in this research study will last about 2hours and 15 minutes. Each lesson will last for 45 minutes. Regarding the interviews, one interview session will be conducted before the first lesson, one after the first lesson and a third one after the second lesson. Each interview will last for 15 minutes. The interviews and lesson observations will take place in your classroom after the teaching hours on agreed dates.

With your permission, I would like to audio record the interviews and video record the lessons. Kindly note that neither your face nor the faces of your learners will be shown in the video to protect your privacy. The data that will be retrieved during the interview sessions and lesson observations will be stored in for future secondary analysis in a google drive that will have an encryption/strong password that only me and my supervisor can access.

The interviews will be confidential and anonymous. When I share the results of the research study, I will not include your name or anything else that could identify you such as the name of your school, or the district of your school. With your permission, other researchers may use the data collected from this research study, but your name and any personal information will not be used or passed on.

If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits, or rights you would normally have if you chose not to join. Taking part in the research study will not cost you anything. You will not be paid for being in this research study.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za

Yours sincerely,

SIGNATURE

RESEARCHER: Ritha Mazibuko

EMAIL: 1637682@students.wits.ac.za.

CONTACT NUMBER: 068 318 7838

SUPERVISOR: Professor Eunice Nyamupangedengu

EMAIL: Eunice.nyamupangedengu@wits.ac.za

CONTACT NUMBER: +27 717 3752

THE CONSENT FORM FOR THE TEACHER

Research Title: Exploring the integration of smartboard when teaching photosynthesis to grade 11 learners.

Name of the researcher: Ritha Mazibuko

I,………………………………………………….., agree to participate in this research project.

I agree to the following:

(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about
YES/NO

I understand that I can volunteer to take part in this study
YES/NO

I understand that the interview/focus group/other activity may be audio recorded
YES/NO

I understand that the lessons will be video recorded

YES/NO

I agree that direct quotations from my interviews/focus group/other activity may be used by the researcher in their research report/manuscript/book chapter
YES/NO

I agree that my participation will remain anonymous (my name will not be used by the researcher in their research report/manuscript/book chapter)
YES/NO

I agree that other researchers may use the information I provide in my interview/focus group/other activity (depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on
YES/NO

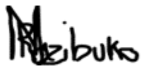
I agree that the information I provide may be used in an anonymized format after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.

YES/NO

………………………………………..(signature)

………………………………………..(name of the participant)

………………………………………..(date)

 (Signature of the researcher)

Ritha Mazibuko (signature of the researcher)

.... (date)

APPENDIX 5: Information Letter for Parents and Consent Forms

PARTICIPANT INFORMATION LETTER FOR THE PARENT

Good day,

My name is Ritha Mazibuko, I am a master's student at the University of the Witwatersrand, Johannesburg. My supervisor is Professor Eunice Nyamupangedengu. I am conducting a study on how teachers integrate smartboard into their life sciences classrooms, particularly during grade 11 lessons on photosynthesis. The study title is 'Exploring the integration of smart board when teaching photosynthesis to grade 11 learners.'

As part of this research study, I humbly invite your child to take part in two lesson observations. If you decide to allow your child to take part, his or her participation in this research study will last for 90 minutes. He or she will be taught and observed during two photosynthesis lessons, each lesson will last for 45 minutes. The lesson observations will take place in his or her classroom after the teaching hours on agreed dates with his or her life sciences teacher.

With your permission, I would like to video record the lessons. Kindly note that neither the face of your child nor the faces of his or her classmates will be shown in the video to protect their privacy. The data that will be retrieved during the lesson observations will be stored in for future secondary analysis in a google drive that will have an encryption/strong password that only me and my supervisor can access.

When I share the results of the research study, I will not include your child's name or anything else that could identify him or her such as the name of his or her school, or the district of his or her school. With your permission, other researchers may use the data collected from this research study, but your child's name and any personal information will not be used or passed on.

If you allow your child to take part in the research study, it should be because he or she wants to volunteer. He or she does not have to take part. He or she can stop being in the study at any time. He or she does not have to answer any questions if he or she does not want to. He or she will not get any direct benefits if you allow him or her to join the research study. He or she will not lose any services, benefits, or rights he or she would normally have if he or she chose not to join. Taking part in the research study will not cost him or her anything. He or she will not be paid for being in this research study.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za

Yours sincerely,

SIGNATURE

Mazibuko

RESEARCHER: Ritha Mazibuko

EMAIL: 1637682@students.wits.ac.za.

CONTACT NUMBER: 068 318 7838

SUPERVISOR: Professor Eunice Nyamupangedengu

EMAIL: Eunice.nyamupangedengu@wits.ac.za

CONTACT NUMBER: +27 717 3752

Consent Form for a child's parent/legal guardian

Title of project: Exploring the integration of smart board when teaching photosynthesis to grade 11 learners.

Name of researcher: Ritha Mazibuko

I, …………………………………….., agree that my child ……………………..… can participate in this research project.

I agree to the following:

(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.

YES NO

I understand that my child can volunteer to take part in the study

YES NO

I understand that my child has the right to withdraw their participation at any point without any repercussions

YES NO

I agree that the lesson observations with my child may be video, and audio recorded

YES NO

I agree that direct quotations from the lesson observations with my child may be used by the researcher in their research report/ manuscript/book chapter

YES NO

I agree that my child's participation will remain anonymous (my name or other identifying data will not be used by the researcher in their research report/manuscript/book chapter)

YES NO

I agree that other researchers may use the information provided by my child in their lesson observations (depending on their own ethics clearance being obtained) but their name and any personal information will not be used or passed on

YES NO

…………………………………… (signature)

…………………………………… (name of parent/guardian)

…………………………………… (date)

Mazibuko (Signature of the researcher)

Ritha Mazibuko (signature of the researcher)

................................(date)

APPENDIX 6: Information Letter for Learners and Assent Forms

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

PARTICIPANT INFORMATION LETTER FOR THE LEARNER

Good day,

My name is Ritha Mazibuko, I am a master's student at the University of the Witwatersrand, Johannesburg. My supervisor is Professor Eunice Nyamupangedengu. I am conducting a study on how teachers integrate smart board into their life sciences classrooms, particularly during grade 11 lessons on photosynthesis. The study title is 'Exploring the integration of smart board when teaching photosynthesis to grade 11 learners.'

As part of this research study, I humbly invite you to take part in two lesson observations. If you decide to take part, your participation in this research study will last for 90 minutes. You will be observed during two photosynthesis lessons, each lesson will last for 45 minutes. The lesson observations will take place in your classroom after the teaching hours on agreed dates with your life sciences teacher.

With your permission, I would like to video record the lessons. Kindly note that neither your face nor the faces of your classmates will be shown in the video to protect your privacy. The data that will be retrieved during the lesson observations will be stored in for future secondary analysis in a google drive that will have an encryption/strong password that only me and my supervisor can access.

When I share the results of the research study, I will not include your name or anything else that could identify you such as the name of your school, or the district of your school. With your permission, other researchers may use the data collected from this research study, but your name and any personal information will not be used or passed on.

If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits, or rights you would normally have if you chose not to join. Taking part in the research study will not cost you anything. You will not be paid for being in this research study.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za

Yours sincerely,

SIGNATURE

Mazibuko

RESEARCHER: Ritha Mazibuko

EMAIL: 1637682@students.wits.ac.za.

CONTACT NUMBER: 068 318 7838

SUPERVISOR: Professor Eunice Nyamupangedengu

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APPENDIX 7: Lessons Observational Tool

Observational tool

The Refined Consensus Model of PCK: this framework is used to evaluate the extent of integrating smartboard affordances to teach photosynthesis in a grade 11 classroom.

During lesson planning:

The Refined Consensus Model of PCK components	Aspects that will be observed during the lesson.
Collective PCK **Content knowledge** **Pedagogical knowledge** **Knowledge of the learners** **Curricular knowledge** **Assessment knowledge**	The researcher will observe aspects such as the following: • Teachers' ideas as a collective, what they decided include for the lesson and why. • Teachers pedagogical reasoning such as why they choose certain teaching strategies, assessments to give the learners, content to teach the learners. • Learning objectives. • Whether teachers have the required content knowledge. • Identify possible misconceptions and how to address them. • Teaching strategies that the teachers will use to determine learners' prior knowledge. • Whether the diagrams, videos used are adhering to what is said on the CAPS document and the ATP. • Assessments that teachers plan to give the learners.

During the lesson:

The Refined Consensus Model of PCK components	Aspects that will be observed during the lesson.
Personal PCK **Learning context** **Enacted PCK** **Content knowledge** **Pedagogical knowledge** **Knowledge of the learners** **Curricular knowledge** **Assessment knowledge**	The researcher will observe aspects such as the following: • Instances where teachers might be doing what was not part of the planning with the other teachers. • Size of the classroom, whether learners know how to operate the smartboard, how long it takes for the smartboard to switch on (how quick or slow the

	smartboard is), available teaching resources other than the smartboard. • Teacher's pedagogical reasoning such as the teacher's ability to transform their subject knowledge into meaningful learning experiences for learners in real-time classroom settings. • Whether the teacher is teaching the learners the correct content knowledge. • Misconceptions that the teachers identify while teaching and how they correct them. • How teachers identify learners' prior knowledge before teaching the topic. • Whether the teachers will stick to the CAPS document and the ATP and not teach learners content that is not on their levels. • Assessment that the teachers will give the learners during the lesson.

SAMR Model: this framework is used to evaluate the extent of integrating smartboard affordances to teach photosynthesis in a grade 11 classroom.

The research will observe if whether the teacher will be doing the following:

- Writing on the smart board.
- Drawing on the smart board.
- Playing a simulation video that illustrates the process of photosynthesis.
- Colouring and annotating diagrams.
- Using a PowerPoint presentation to either introduce or summarise key concepts of photosynthesis.
- Displaying a QR code for sharing resources with learners or links for class tests.
- And more.

APPENDIX 8: Lesson Observational Transcripts from school 1 for lesson 1.

Jade: Morning everyone. Did I greet? I don't remember.

Learners: Morning Ma'am.

Jade: OK, Uh thank you for showing up. Probably this will be as efficient as it should be. Mm remember we said you have a problem with photosynthesis. So, we are trying to to to do do something about that problem. So, over there at the back I have uh, do I call you your first name? do I call you the last name? OK uh, Ms Mazibuko right there. Um hmm.

Learners: Shine.

Jade: Shine Ms Mazibuko shine.

Learners: Shine.

Jade: Uh alright. So, she's gonna be helping me uhmm with this photosynthesis thing because it looks like the problem is me here between me and you. But anyways I still believe the problem is not me. OK uh photosynthesis. I have a diagram (SAMR) (pedagogical knowledge)-**ePCK.** right there on the board, two pictures rather. Um what comes into mind when you're seeing these pictures? (knowledge of the learners)-**cPCK**. Remember whatever you're thinking about relate it to this topic of photosynthesis (curricular knowledge)-**cPCK** right now. What comes into mind when you're seeing this diagram(SAMR)? Um mm.

Learners: Mumbling.

Jade: Yes.

Learner 1: Green pigment on the leaves (knowledge of the learners)- **ePCK**

Jade: OK, someone is saying the green pigment. This person is thinking so much. OK, the green pigment that is found on the leaves.

Learner 2: Madam.

Jade: Yes, uh huh.

Learner 2: The green pigment it shows that photosynthesis is occurring (knowledge of the learners)- **ePCK**

Jade: It shows that photosynthesis is occurring. So, it's the pigment that makes photosynthesis occur. I wanna know what this pigment. OK. What comes on your mind when you see that green picture. Yes.

Learner 3: When I look at that picture, the diagram(SAMR), I think of what comes to my mind is trees growing taller competing for sunlight (knowledge of the learners)- **ePCK**

Jade: Trees that are growing tall, Ok. As they are growing taller you are saying also they are competing.

Learner 3: To get sunlight (knowledge of the learners)- **ePCK**

Jade: And they are competing for? (pedagogical knowledge)-**cPCK**

Learners: Competing, to get enough sunlight (knowledge of the learners)- **ePCK**

Jade: Sunlight, OK. So, everyone wants sunlight. OK what else? (pedagogical knowledge)-**cPCK** ...Uh hm.

Learner 4: The exchange of oxygen and carbon dioxide.

Jade: The exchange of oxygen. OK, the exchange of oxygen as well as carbon dioxide (pedagogical knowledge)-**ePCK**..Anything else? Yes.

Learner 5: *Inaudible.*

Jade You are thinking about the water. Is the water enough? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Jade: OK, what will make the water enough maybe? (pedagogical knowledge) -**cPCK**

Learners: Madam, if there is rainfall.

Jade: If there is rainfall (pedagogical knowledge)-**ePCK**…So, probably something also about the rainfall. I don't know also. Anything else? (pedagogical knowledge) -**cPCK**

Learner 6: Irrigation.

Jade: Irrigation. Uh hm. What else? (pedagogical knowledge)-**cPCK**. OK, so these are ideas but what is this pigment? I see that you talk, spoke about the green pigment. What is this pigment? Yes.

Learners: Inaudible

Jade: OK, you also think of chlorophyll. Maybe because someone thought of whether photosynthesis is occurring. What will result in photosynthesis occurring? (pedagogical knowledge) -**cPCK**

Learner 4: Madam.

Learner 7: Starch will be produced in the plant (knowledge of the learners)- **ePCK**

Jade: What will be produced in the plant? (pedagogical knowledge) -**cPCK**

Learners: Starch (knowledge of the learners)- **ePCK**

Jade: What will be produced? (pedagogical knowledge) -**cPCK**

Learner 7: Starch (knowledge of the learners)- **ePCK**

Jade: Oh, you're saying starch will be produced? (pedagogical knowledge) -**cPCK**

Learner 7: Yes.

Jade: Oh, so you're also thinking about the starch. Ei, I teach smart learners , (Pedagogical knowledge)-**pPCK** neh. I don't know, did you went through this lesson?(pedagogical knowledge) -**cPCK**

Learners: Yes.

Jade: Huh?

Learners: Yes.

Jade: I doubt it, (Pedagogical knowledge)-**pPCK** my learners looked at the picture(SAMR) and thought there's something about starch right here. There's something about water going on. There's still more.

Learner 8: I also think about the stomata (knowledge of the learners)- **ePCK**

Jade: The stomata. Ai let's talk about the stomata.

Learner 8: Because uh um, the um, ..*inaudible.*

Jade: There's also a stomata like you said. So, these are pores that found at the surface of the leaf (Content knowledge)- **cPCK**, okay let's move on. So, like we said we are going to touching on photosynthesis, as a whole. Now the aim of the today's lessons or the objective is for you to be able to understand the basic concepts of photosynthesis. So, we want to know exactly what is photosynthesis? What is uh uh um or when you relate the photosynthesis that you have learnt and relate it to all the other biological terms. The aim is to know how to write the word as well as the chemical equation. Remember in grade 8. Or is it grade 8 or grade 9? You learnt about photosynthesis grade 8 and you were writing the word and the chemical equation. So, that was the prior knowledge. We also want to what? (pedagogical knowledge) -**cPCK** Identify um, the role of sunlight, the role of water, the role of chlorophyll, as well as carbon dioxide in this whole process of photosynthesis. We want to describe the two phases of photosynthesis that are there. So, there are two. We have the light phase; we also have the dark phase. So, I'm underlining because it's very important. It needs to be highlighted. OK, describing what? (pedagogical knowledge)-**cPCK** The significance of photosynthesis. Really what are we doing if we do not know the importance of photosynthesis, as a whole, OK. Now over right here. I think these are words that you have heard of somehow. So, I need us to define these words. Number one is photosynthesis. So, these are the biological terms that you will probably see in your exam, you will probably see somewhere. Number one, photosynthesis. Let us define what is photosynthesis. Yes.

Learner 4: Is a process where green plants make their own food (knowledge of the learners)- **ePCK**

Jade: Process where green plants. So, it's a process whereby green plants manufacture their own food, right, OK. Is there anything different huh? Is there something we need to add on photosynthesis? (pedagogical knowledge) -**cPCK** I believe there is (pedagogical knowledge)- **pPCK**

Learners: Yes.

Jade: Yah, what is photosynthesis? (pedagogical knowledge) -**cPCK** Yes.

Learner 9: Um, it's a process whereby green plants make their own food (knowledge of the learners)- **ePCK**

Jade: Uh hm.

Learner 9: Um, yeh?, in a form of glucose (knowledge of the learners)- **ePCK**

Jade: Their food is in a form of glucose. What are the, what what is being used in photosynthesis to make this food? (pedagogical knowledge)-**cPCK**, maybe lets to that as well. Yes.

Learner 4: Radiant energy (knowledge of the learners)- **ePCK**

Jade: Radiant energy, that what you learnt in grade 8 (content knowledge)-**cPCK.** Using radiant energy from the sun, OK. Number two, there is a rather term right there, photolysis or photolysis OK. For you to be able to define remember you tell us what is the meaning of photo... What is the meaning of lysis? (pedagogical knowledge)-**ePCK.** Or if you know the full word what do you think it means? What is the meaning of photolysis? Yes.

Learner 12: I think um we use radiant energy (knowledge of the learners)- **ePCK**

Jade: We use radiant energy (pedagogical knowledge)-**ePCK**

Learner 12: To separate the certain compounds (knowledge of the learners)- **ePCK**

Jade: Using radiant energy to separate certain compounds. Photolysis, alright so from the word photo it means what? (pedagogical knowledge)-**cPCK** Light, and then lysis you are breaking down something. So, it means that you are using light OK, in order to break down organic compounds. Using light to break down organic compounds (pedagogical knowledge)- **cPCK**.I think it's important that you write, that's why I'm writing (pedagogical knowledge)-**cPCK** because at the end at the end there is gonna be a small lesson. Probably we will be asking you about all these things that we just said, ok. And then the next one is chlorophyll. So, chlorophyll is a substance. What is chlorophyll? (pedagogical knowledge)-**cPCK** Anyone with an idea? Yes.

Learner 4: Madam, it is a green pigment (knowledge of the learners)- **ePCK** …*inaudible.*

Jade: This is a green pigment (pedagogical knowledge)-**ePCK**….OK. The green pigment that is found in leaves. Where is it exactly in the leaves? (pedagogical knowledge) **-cPCK**

Learner 4: In the…

Jade: Where is it in the leaves? (pedagogical knowledge) -**cPCK**

Learners: In the chloroplast (knowledge of the learners)- **ePCK**

Jade: In the chloroplast (pedagogical knowledge)-**ePCK**…Now what is the chloroplast? What is a chloroplast? (pedagogical knowledge)-**cPCK**...Yes.

Learner 3: I think we should add that uh chlorophyll is responsible for trapping sunlight (knowledge of the learners)- **ePCK**

Jade: We should add the chlorophyll is OK. So, she's saying uh responsible for trapping sunlight, OK. Maybe somewhere some we will learn about chlorophyll and how exactly it traps that sunlight. And then we also have a chloroplast. Moving on, the chloroplast is an organelle and if it's an organelle, it's an organelle this is the, where photosynthesis takes place, OK. Where photosynthesis takes place. And then we also have another new term which is called phosphorylation. So, when you are talking about phosphorylation we are talking about the formation of ATP and how is it formed. It is formed from the addition of a phosphate group that's what we said, to an ADP molecule. Do you remember that, remember ADP? Adenosine diphosphate. I said they have two phosphate groups. So, for ATP, which is adenosine triphosphate to be formed there needs to be another phosphate group that needs to be added. So, we said that was called phosphorylation, OK. You're not convinced (pedagogical knowledge)**- pPCK**, I know. Adenosine triphosphate. What was ATP? This is the energy carrier or it's actually just energy OK. And then glucose, this is your organic compounds, the organic compounds that is formed at the end of photosynthesis. And then the last term we have right there is NADP, probably a new term but not as new. This is nocotinamide adenine dinucleotide phosphate, OK, um yes, I often uh uh uh stopped you from knowing this and I used the word co-enzyme (Content knowledge)-**pPCK**.. Do you remember that?

Learners: Yes.

Jade: So, NADP is the co-enzyme that we spoke about. So, co-enzymes that are also working in carrying hydrogen, hydro, hydrogen molecules (Content knowledge)-**pPCK**. We'll talk more about them as we move. I know my handwriting is the best. OK, just the few biological terms for this lesson. Number one, we have photosynthesis, we said this is the process whereby green plants manufacture their own food and what are they using? They are using radiant energy, OK. And then someone also added that this food is glucose (knowledge of the learners)-**ePCK**, so it's in the form of glucose, OK. And then we moved and looked at photolysis. We said photo means light and lysis means you're breaking down. OK. So, it means that you're using light in order to break down organic compounds, OK. And then with chlorophyll this is a substance, it is a green pigment that is found inside the chloroplast, and it is responsible for trapping sunlight, OK. And then we have a chloroplast which is an organelle where you find tis chlorophyll and its an organelle where photosynthesis takes place OK. We have phosphorylation which is the formation of ATP from the addition of the phosphate group to ADP. We also have adenosine triphosphate, which is ATP. Which we said is the energy or the energy carrier. We also have glucose which is the organic compound that you have been talking about since last year. And then we have NADP which is a coenzyme that carries hydrogen molecules OK. Can I move from here?

Learners: Yes, no.

Jade: Why is there a no?

Learner 3: I think you can move; I think you can move forward (pedagogical knowledge)-**pPCK**..Madam.

Jade: You think I can move forward? (pedagogical knowledge)-**cPCK**

Learner 3: Yes.

Jade: Thank you learner 3 (pedagogical knowledge)-**cPCK**, I will definitely move forward. Alright, now, moving forward I need us to look at the requirements of photosynthesis. So, there are two or three, or whatever the case. I don't know really, but looking from these diagrams(SAMR) that you are seeing right here, what do you think are the requirements of photosynthesis? (pedagogical knowledge)-**cPCK** ...From these pictures(SAMR) that I have right on the board. What do you think are the requirements of photosynthesis? (pedagogical knowledge)-**cPCK** ...Yes.

Learner 13: Water (knowledge of the learners)- **ePCK**

Jade: Number one you are saying it is water (pedagogical knowledge)-**ePCK**. OK, so, she's seeing water right there. Yes.

Learner 14: Sunlight (knowledge of the learners)- **ePCK**

Jade: Sunlight as well as (pedagogical knowledge)-**ePCK**, what is the last one? (pedagogical knowledge) -**cPCK** ...Yes.

Learner 14: Carbon dioxide (knowledge of the learners)- **ePCK**

Jade: Carbon dioxide, (pedagogical knowledge)-**ePCK** OK. So, I'm glad we have all seen this, not the first time seeing this is the water. What is the chemical formula of water? (pedagogical knowledge)-**cPCK**

Learners: H_2O (knowledge of the learners)- **ePCK**

Jade: H_2O (pedagogical knowledge)-**ePCK** okay it's the big 2? (pedagogical knowledge) - **cPCK**

Learners: No.

Jade: Where should I put the 2? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Jade: Huh? Oh, at the bottom. Oh, H_2O. And then we have sunlight as well as carbon dioxide and the chemical formula.

Learners: CO_2 (knowledge of the learners)- **ePCK**

Jade: CO_2. We have a small 2 there, a subscript of 2. OK, so it is important for you to know that for photosynthesis to occur, there needs to be um, some eh eh eh organelles present, or some requirements present OK. One of the requirements is water, another one is sunlight, and then another one is carbon dioxide (Content knowledge)-**pPCK**.. I think there is one requirement missing. Yes.

Learner 15: I think its light intensity.

Jade: You think? (pedagogical knowledge) -**cPCK**

Learner 15: Light intensity.

Jade: It will be in the form of sunlight (pedagogical knowledge)-**ePCK**…Yes.

Learner 3: Ma'am I think the presence of chlorophyll because…*inaudible.*

Jade: OK, there's nothing mentioned about chlorophyll right here, OK. So, we also need chlorophyll in a way so that we are able to undergo this, or the plants are able because its not us anyways. OK, uh alright and then the products of photosynthesis, so, at the end we get what we call the products. Remember I said they are also called by-products, or they are also called what? (pedagogical knowledge)-**cPCK** The end-product, as long as you know the the end we get two also products (pedagogical knowledge)-**ePCK.** What product is this? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)- **ePCK**

Jade: Oxygen, so its oxygen in the form of a gas (pedagogical knowledge)-**ePCK** and then what els…what's the other product? (pedagogical knowledge)-**cPCK**

Learners: Glucose (knowledge of the learners)- **ePCK**

Jade: This is glucose, OK. So, we get two products at the end of photosynthesis. First one being oxygen, and then second one being glucose. So, its very important that you know how to write this glucose properly. I used to say that there are six carbons, there are only twelve hydrogens, and then you go back to the six oxygens. OK, so it is double the number of hydrogens. Eh and then with the carbon and the oxygen it's just one eh eh eh which is just six of them (Content knowledge)-**pPCK**. OK. Now, just on this diagram(SAMR) (pedagogical knowledge)?-**cPCK** I have picture(SAMR) of plants OK. So ,as the reminder of what you did probably in grade 10, grade 8 (content knowledge)- **cPCK.** A picture (SAMR)of plants, remember when we started, actually this year beginning of the year we said plants fall into the kingdom of plantae and why was the plant a kingdom of plantae? (content knowledge)- **cPCK**…That was because they had, or they are eukaryotes. What does been an eukaryote mean (pedagogical knowledge)?-**cPCK**

Learners: *Inaudible.*

Jade 1: What's the meaning of a eukaryote? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Jade: Yes. Eukaryotes? (pedagogical knowledge) -**cPCK** Um hm.

Learner 16: They have a definite nucleus (knowledge of the learners)- **ePCK**

Jade: They have a definite nucleus (pedagogical knowledge)-**ePCK**.. So, you say the reason why they are eukaryotes it is the definite nucleus and then last one learner 4, they are autotrophs, what's the meaning of autotrophs learner 4? (pedagogical knowledge)-**cPCK** ....Learner 4 I'm talking to you.

Learner 4: Eh they are what's this? Producers (knowledge of the learners)- **ePCK**

Jade: Sorry!

Learner 4: They are producers (knowledge of the learners)- **ePCK**

Jade: They are producers (pedagogical knowledge)-**ePCK**.. Learner 4 you said they manufacture their own food, but now you are not giving me that that answer OK. So, just plants are found in the kingdom plantae, very important to know, and also, they are eukaryotes which means they have a definite nucleus and the fact that they are autotrophs which means they are able to manufacture their own food, OK. Same as this is grade 10 (Content knowledge)-**pPCK**.. If you remember in grade 10 you drew a structure of a leaf. Did you? (content knowledge)-**cPCK.**

Learners: Yes.

Jade: OK, you were supposed to draw a structure of the leaf where in the leaf, I said on the top section or the top part of the leaf we have a cuticle, and we said this is a thin waxy layer remember? Yah, I'm not gonna remind you. And then we have the epidermis following that and then we have two mesophyll tissues. We have the palisade mesophyll which was elongated. We have a spongy mesophyll which is circular and all of them inside have chloroplasts. In between you have the xylem, you have the phloem to transport the water, the mineral salts. You had the guard cells; you had the stoma which is the stomata, and you also had some veins. So, this is just a reminder of how exactly a leaf looks. So, when we talk about probably the requirements of photosynthesis you need to think about everything that is happening in the leaf. (content knowledge)-**cPCK** How exactly is this light reaching these…inaudible…because we said this is where you find these uh uh uh what do you call them? I am forgetting the register. Learner 3 I'm gonna use your book neh.

Learner 3: No problem Madam.

Jade: So, when it come to you, don't take it. 11D and G right? Or are you separated? What's the date today?

Learners: 13th.

Jade: 13th?

Learner: Yes.

Learners: Whispering.

Jade: Uh this thing just made my paper dirty. Please write your number num…name and sign. Okay and then on this slide, I have a diagram(SAMR) (pedagogical knowledge)-**cPCK** that is showing a chloroplast. So, in a chloroplast you need to remember that we spoke about the fact that um there is doub…a double membrane. We said there in an outer membrane which is what you are seeing right there. And then number two there is an inner membrane so that's a double membrane we spoke about, OK. And then number three we spoke about the fact there are, there's stacks of disks that exist inside(content knowledge)-**cPCK** and each stack what is it called? (pedagogical knowledge)-**cPCK** ...Each disk I mean.

Learners: It is the lamella (knowledge of the learners **)-ePCK**

Jade: It is the lamella, (pedagogical knowledge)-**ePCK**… or also called what? The thylakoid, right, OK. And then we said all these disks combined, what are they called?(pedagogical knowledge) -**cPCK**

Learners: Granum (knowledge of the learners)- **ePCK**

Jade: They are called a granum, OK. And then what else is um, is clear right? OK, There is no mention, or there is it. Mention of the ribosomes. So, there are ribosomes that are also important in eh eh the chloroplast. On the side you then have the diagram(SAMR) of the same thing, the same eh eh chloroplast, but this is a micrograph, OK. (Content knowledge)-**cPCK** What did we say was the micrograph again? (pedagogical knowledge)-**cPCK**

Learners: Picture.

Jade: Picture.

Learners: Taken from a microscope (knowledge of the learners)- **ePCK**

Jade: Taken from a microscope. So, after looking at the microscope its either you went and drew, and this is what you saw. Or you took a picture depending on the type of microscope that you have. Alright, just a bit, lets touch on the requirements not requirements. Um the adaptations of the chloroplast for their function. OK, so we said there is a granum, there's a thylakoid, there's a ribosome, there is also a stroma. No one is reminding me of the stroma. There is also a stroma, there is uh the membrane. What was the importance of the double membrane? Or the adaptation of the chloroplast with reference to the double membrane? (pedagogical knowledge)- **cPCK** Yes.

Learner 17: Um, the double membrane it allows easy entry of water in the membrane (pedagogical knowledge)-**ePCK**

Jade: Ok, you're this allows for entry of water as well as carbon dioxide, OK. (pedagogical knowledge)-**cPCK** ...Find something else there that I did not mention. Uh hm.

Learner 18: Um, the stroma which contains enzymes for the dark phase (knowledge of the learners)- **ePCK**

Jade: We said there is a stroma that contains enzymes (pedagogical knowledge)-**ePCK**

to be used for the dark phase OK. What else? (pedagogical knowledge)- **cPCK**

Learner 3: Ma'am you forgot to mention that you forgot to mention that there is a starch grain. (knowledge of the learners)-**ePCK**

Jade and learners: *Inaudible.*

Jade: There's a starch, yes (pedagogical knowledge)-**ePCK.** it's not visible in my diagram. So now I'm adding it neh. This is a starch grain according to me. I don't know how yours looks like, but this looks like mine, Ok. So, there's a starch grain Ok. What is the function of the starch grain or the adaptation? Uh hm.

Learner 3: It stores the uh starch…*inaudible*… to convert to glucose.

Jade: Huh?

Learner 3: I'm saying starch will be stored as ampules.

Jade: I'm giving you a chance again (pedagogical knowledge)-**pPCK**

Learner 3: You want me to give you the, what's the …*inaudible*…

Jade: What, what is the function of the starch again?(pedagogical knowledge)- **cPCK**

Learner 3: It stores glucose (knowledge of the learners)- **ePCK**

Jade: In the form of?(pedagogical knowledge)- **cPCK**

Learner 18: Of starch.

Learner 3: It stores starch in the form of glucose Ma'am.

Learner 18: No.

Learner 3: Yes! That's what's written in the textbook (pedagogical knowledge)-**ePCK**

Jade: Aright, there is a starch grain that is storing starch OK or storing glucose in the form of starch. And then we have something else. There's a granum we haven't mentioned. There's a thylakoid, there's a ribosome that you haven't mentioned any adaptation form. Yes. (Content knowledge)-**pPCK**.

Learner 4: Uh, ribosomes forms enzymes for photosynthesis.

Jade: Yes, we have the ribosomes which forms enzymes and what are these enzymes for?

Learner 4: Photosynthesis.

Jade: Huh?

Jade and learners: Protein synthesis.

Jade: It is for protein synthesis.

Learner 4: *Inaudible.*

Jade: It is for protein synthesis (pedagogical knowledge)-**ePCK**, for the manufacturing of proteins. For proteins to be made, yes.

Learner 19: The lamella.

Jade: The lamella (pedagogical knowledge)-**ePCK**, where is the lamella? Uh huh, what about the lamella? (pedagogical knowledge)- **cPCK**

Learner 19: *Inaudible*

Jade: The the lamella, which is the thylakoid in this case, it contains what? (pedagogical knowledge)- **cPCK**

Learners: The chlorophyll.

Jade: Chlorophyll contains chlorophyll (pedagogical knowledge)-**ePCK** What is the function of chlorophyll? What is the function of function chlorophyll? (pedagogical knowledge)- **cPCK** ...Yes.

Learner 20: It is to trap sunlight (knowledge of the learners)- **ePCK**

Jade: It is to trap sunlight, OK. The granum is doing the same thing right. Because it contains the lamellas, it means it is there to trap the sunlight. Now let's get into probably the second last part before we take a break. We have two types or two phases that occur in photosynthesis. So, we have number one, the light phase which is the light dependent phase of photosynthesis as well as the light independent phase. So, we will talk about both of them but right now let's look at this diagram(SAMR) and look at what is happening exactly right here, OK. So, the light dependent phase of photosynthesis takes place in the grana (Content knowledge)-**pPCK**.. Why is it taking place in the grana? We said what is there in the grana that allows this to occur? (pedagogical knowledge)- **cPCK**

Learners: Chlorophyll.

Jade: There is chlorophyll (pedagogical knowledge)-**ePCK**.. So, there is a lamella, and the lamella, what does it do? We said it contains what? (pedagogical knowledge)- **cPCK**

Learners: Chlorophyll.

Jade: Chlorophyll. OK. So that is very important. So, it means that for this light dependent phase to occur there needs to be light present, hence the first thing that you need to look at is presence of this sunlight, OK. So now the presence of this sunlight which is giving off what? Radiant energy and over right here I have a structure of the leaf and in the structure of the leaf I'm trying to look at all the components that are there in the leaf, Ok (Content knowledge)-**pPCK**. So, the radiant energy eh will be what? Will be trapped by the, what? The grana which is found in the leaf and then it is trapped by the grana found in the leaf. What will happen?(pedagogical knowledge)- **cPCK** ...It will split water into hydrogen molecules as well as oxygen. So, we said this hydrogen is highly energised hydrogen atoms, OK. So, I'm just going to add a small 'e' here to show that they are energised hydrogen atoms. And then this oxygen what will happen to it? This oxygen we said it is taken to the dark phase (content knowledge)-**pPCK** ...So, the oxygen is not used in this light phase that we are in. And then we said, the hydrogen that is eh eh eh eh split or formed from the split of eh this photolysis happening right here of this water, it will be carried to the dark phase and what is it using? It is using a coenzyme. What is the name of the coenzyme now that you know something?(pedagogical knowledge)- **cPCK**

Learners: NADP.

Jade: NADP, OK (pedagogical knowledge)-**ePCK**…The coenzyme NADP will carry that hydrogen molecule, and it will carry it to the dark phase. We forgot one thing. So, during the splitting of water there's also ATP that is eh eh eh eh eh that comes about it as well. This ATP will also be used in the light independent phase (Content knowledge)-**pPCK**. And then in the light independent phase, where does it take place? (pedagogical knowledge)- **cPCK**

Learner 19: Stroma.

Jade: It takes place in the stroma of the chloroplast. Why in the scloma uh stroma? (pedagogical knowledge)- **cPCK**...That is because that is where the enzymes for the dark phase are present and there is no lamella in there that will trap the chlo uh uh sunlight, OK. Now in here's are energy rich carbo eh eh eh hydrogen and (Content knowledge)-**pPCK**. now this energy rich hydrogen is combining with what (pedagogical knowledge)- **cPCK**? ...Carbon dioxide, where is this carbon dioxide coming from? It is coming from the atmosphere, OK. It combines with the energy rich uh energy rich hydrogen combines with carbon dioxide from the atmosphere together with that ATP that is coming from the dark phase (content knowledge)-**pPCK**. What is it going to form at the end? It is forming the glucose molecule. Again, what is the chemical formula since it looks like we are using chemicals here.

Jade and learners: $C_6H_{12}O_6$

Jade: OK, So the carbon dioxide combines with the hydrogen molecules to form uh uh the ATP together to form the energy rich molecules which are called glucose. The the the organic molecule, OK. And then right here at the bottom you have eh eh this is supposed to be your starch grain, which is now going to store these starch granules, OK (Content knowledge)-**pPCK**.. Does that make sense? (pedagogical knowledge)- **cPCK**

Learners: Yes.

Jade: Can we move? (pedagogical knowledge)-**pPCK**

Learners: Yes.

Jade: Alright, so this is repeating the same thing really. Uh, in the light phase the water is split into hydrogen. So, energy, energised hydrogen atoms as well as oxygen. The oxygen is released into the atmosphere and what happens with the hydrogen? It combines with that ATP with the co-enzyme importantly, with the coenzyme and then all three are taken into the dark phase. So, they are taken into the stroma. So, here they are , you get your energised hydrogen atom. You still get your ATP in this diagram(SAMR) as well as your carbon dioxide that is coming from the atmosphere. And all three of these now are going to produce a by product which is glucose (content knowledge)-**pPCK**. Is there anything I need to repeat there? Yes.

Learner 20: Inaudible.

Jade: Sorry, from the splitting of water molecules. When you're splitting the water ATP also results (content knowledge)-**pPCK**. Anything I need to repeat? Can I move? (pedagogical knowledge)-**pPCK**

Learner 19: Madam.

Jade: Yes.

Learner 19: *Inaudible.*

Jade: Radiant energy. The energy from the sun (Content knowledge)-**pPCK**, we can move now.

Learners: Yes.

Jade: Thank you, Ok. This is a chemical equation of photosynthesis. So, we are looking at, firstly, we said in a chemical equation at the beginning we have what we call the requirements of photosynthesis OK, and there at the end what do we have? We have what we call a product of photosynthesis. So, carbon dioxide combines with water in the presence or using the energy from the sun this energy from the sun is trapped by the chlorophyll that is in the plants to produce this sugar which is a glucose molecule as well as the gas which is oxygen (Content knowledge)-**pPCK.** OK, you still remember this formula right? (pedagogical knowledge)-**cPCK** OK can we move from here? (pedagogical knowledge)-**pPCK**.

Learners: Yes.

Jade: Yes, thank you (pedagogical knowledge)-**pPCK**. And then, this is just a summary of everything that we have said so far, OK. You have your leaf, in the leaf we said you have structures that are right there, the anatomy of the leaf. We said you have your mesophyll tissues. I'm not going to highlight those, because the mesophyll tissues have this structure that we are looking for, OK. They have the chloroplast that we want to look at. And then in the chloroplast what do we zoom into? We zoom into the grana as well as the stroma. OK, the grana, what did we say about it? We said it traps what?(pedagogical knowledge)- **cPCK**

Jade and learners: Sunlight.

Jade: When it traps sunlight what will the occur? (pedagogical knowledge)- **cPCK** ...Photosynthesis can then occur properly resulting in the production of carbon dioxide as well as (content knowledge)-**pPCK** …carbon dioxide?(pedagogical knowledge)- **cPCK**

Learners: Oxygen.

Jade: You're agreeing though. Resulting in the production of oxygen and as well as sugar molecule. Can you see?

Learners: Yes.

Jade: OK, oxygen and sugar is been produced whereas water and carbon dioxide was used. Even the arrows are moving in to show that is the requirements. Now, from this picture,(pedagogical knowledge)**-cPCK** I'm tired of talking. I've been talking, yah let me give you a chance to talk, and as you talk I need you write something for me on the board. What is the significance of photosynthesis? I don't know if this picture(SAMR) really has anything that tells you the significance of photosynthesis, but I need someone to tell me, and you need to tell me by standing here and teaching us or writing cause I'm tired. Yes learner 3 (Pedagogical knowledge)- **pPCK**

Learner 3: Ma'am can I just say what my thought are cause yho Ma'am my writing is not good.

Jade: Your handwriting is better than mine.

Learners: Laughing (pedagogical knowledge)-**pPCK**

Jade: Your handwriting is way better than mine.

Learner 3: I disagree.

Jade: Let me be the decider learner 3.

Learner 3: OK Ma'am.

Jade: I'm tired of talking really.

Learners: Whispering.

Learner 3: OK, alright, uh we spoke about, if you remember very well the process of photosynthesis that carbon dioxide was taken in and then oxygen is the is the by product of the process OK. So, my understanding when I think of it, especially when I look at this diagram(SAMR) I then think of global warming. The carbon dioxide in the atmosphere and I see trees taking uh natural part, part and parcel in addressing global warming by releasing uh oxygen and taking in CO_2. That's what I think, so that's the significant part for me. Them taking part and parcel in the global warming issue (pedagogical knowledge)-**ePCK.**

Jade: Thank you, someone else please (pedagogical knowledge)- **pPCK** So, learner 3 emphasise that the trees that are there are important because they are giving us oxygen. Number two, they are uh uh taking in what?(pedagogical knowledge)- **cPCK**.. The carbon dioxide, now what does this mean? As the importance of photosynthesis.

Learner 20: Regulating.

Jade: Huh?

Learner 20: Regulate the uh…

Jade: It's regulating the levels of oxygen, uh man the concentration of oxygen as well as carbon dioxide in the atmosphere (pedagogical knowledge)-**ePCK**. Does that make sense?(pedagogical knowledge)- **cPCK**

Learners: Yes.

Jade: OK, what else, one other person. Learner 21 I'm nominating you (pedagogical knowledge)- **pPCK** Any of the…Oh yes, OK.

Learner 20: It provides food for…inaudible…

Jade: It provides food for organisms that in the higher energy or trophic levels. So, for example, there is that what is that? Kangaroo, what is it?(pedagogical knowledge)- **cPCK**

Learners: It's a kangaroo.

Jade: Huh? It's a kangaroo, (pedagogical knowledge)-**ePCK**..Ok. There is a kangaroo right there. This is an animal that cannot manufacture their own food. So, learner 20 is saying this photosynthesis is providing food for this example, kangaroo right there, OK. Is there anything else? Anything that you would like to mention? (pedagogical knowledge)- **cPCK** ...Uh hm.

Learner 21: Um ventilation for animals (knowledge of the learners)- **ePCK**

Jade: So, you're saying ventilation. OK, what do you mean by ventilation? (pedagogical knowledge)- **cPCK**

Learner 21: Um, plants give us oxygen and uh animals give off carbon dioxide which is needed for photosynthesis (knowledge of the learners)- **ePCK**

Jade: Plants take in carbon dioxide, and they give off oxygen that is needed for animals. (pedagogical knowledge)-**ePCK**..You are right (pedagogical knowledge)- **pPCK**.., OK, anything else, Learner 1 your hand was up.

Learner 1: Uh, some of the plants break down dead organisms or…? (knowledge of the learners)- **ePCK**

Jade: Some of the plants, some of the animals they will break down the dead organic matter, so they act as what? (pedagogical knowledge)- **cPCK**...Decomposers, so they break down the dead organic matter in order to do what? To release nutrients to the atmosphere. Alright, so over here I have a video(SAMR) (pedagogical knowledge)-**cPCK**…*inaudible*… let's see OK, let us list… oh the voice is not there. I am the voice, so you are going to listen to me again. Alright se have green plant right here. So, we want to summarise everything that we have done, and we are looking still at photosynthesis. For photosynthesis to occur we have radiant energy from the sun. Why is it not giving me the option of pausing? Yes, there's radiant from the sun that will do what? That will combine with carbon dioxide and as well as wat..,carbon dioxide and water and then because these plants are green they have what we call what? (pedagogical knowledge)- **cPCK**

Jade and learners: Chlorophyll.

Jade: To trap what? (pedagogical knowledge)- **cPCK**

Jade and learners: The sunlight.

Jade: And then what are they going form?(pedagogical knowledge)- **cPCK** ...Let's see if this person continues. They are forming energy; oh, they are forming sugars first which is glucose as well as oxygen. OK, so what was important was to know that there is energy that is coming from the sun. solar energy, OK, we are no longer using the word solar, so don't use solar. Let me pause, yes. Energy from the sun combining with carbon dioxide together with water to form what?(pedagogical knowledge)- **cPCK** ...This eh eh eh high energy molecule glucose as well as oxygen. So, this is just a balanced chemical equation. Don't look at it and think there is something new. In grade 8, grade 8 grade 9, you balanced that there are six carbons here, It means this side there needs to be six carbons (content knowledge)-**cPCK..** But for now, you don't need to know all of that. OK, let's see, the video(SAMR) is going on and what do they want us to know about. Oh, whatever I wrote. So, this is showing you that photosynthesis is occurring there in a plant cell. Where exactly in a plant cell? (pedagogical knowledge)- **cPCK**

Jade and learners: In the structure of the chloroplast.

Jade: As it occurs in the structure of the chloroplast, where is it occurring? The light reaction? It is occurring in the grana. Because we said the grana has what? (pedagogical knowledge)- **cPCK**

Jade and learners: Chlorophyll.

Jade: Chlorophyll is the one that was trapping light. So, the grana is also called, the lamella is also called the thylakoid. OK, so it traps light, there is it, we are seeing phosphorylation occurs. And then let's see what is formed. Water is also needed as a requirement. It starts producing oxygen. Let me pause, this is moving too fast for my liking. OK, so light is being trapped by the lamella and then there is addition of water. That water is split into oxygen molecules, okay we do not see the hydrogen. So, I'm guessing it's already in the stroma. OK, lets move on. Is it going on? There we go, so now we want to see the hydrogen, so yes, the hydrogen are there in the stroma that what it looks like and then phosphorylation occurs. When this phosphorylation is occurring, the carbon dioxide from the atmosphere combines with the hydrogen that was energised to form the carbohydrates which are the sugars. OK, is there anything that needs repetition? I think this video summarises everything that we have done so far. This person can now talk on their own (content knowledge)- **pPCK.** Anyone who wants to tell us what's happening here? (pedagogical knowledge)-**ePCK.** Anyone who wants to stand and say this is this and that? Like I was rushing, yes uh hm. I always say the more you talk about it, the more it gets better. So, press the screen anywhere, yes.

Learner 1: Um, ngicel'ungiboleke *(please borrow me)*. Uh, so everyone right now, in this diagram(SAMR) actually the requirements for photosynthesis to occur. The requirements for photosynthesis to occur are water, uh carbon dioxide, light energy and what you may not see because um the. Alright, so because the plant green we can then conclude that it has chlorophyll, and which is necessary for also this whole process in order to produce mh our product which is glu glucose and our by product which is oxygen. So, when…inaudible…I don't know, um so when uh the solar energy um and the whole requirements we have a product which is called uh which we have a simple sugar called glucose and its chemical formular is $C_6H_{12}O_6$ uh and then we release oxygen as a by-product. Moving on (pedagogical knowledge)-**ePCK.**

Jade: Just press anywhere (pedagogical knowledge)-ePCK. Uh you've moved on. Its okay, let us continue. Oh, okay thank you. Eh actually stand here, right here. Here's an activity , uh activity says we need to use this diagram(SAMR) to represent the process of photosynthesis but there are things we are not sure of right now. Should I give you a minute to do the whole activity and then we talk about it? (pedagogical knowledge)- **pPCK.**

Learners: Yes.

Jade: One minute. We gonna agree in one minute. Alright, I'm going to use, OK you can take the sit. Are you going to use the timer there? Uh, right, I'm starting the timer (pedagogical knowledge)-cPCK… and then I will go back to the activity.

Learners: Mumbling.

Jade: Uh what is it? The questions are too small?

Learners: Yes.

Jade: Just write the answers, we we are looking for the answers. Don't do a lot of things. Yah that's why we wear glasses. There's a reason why me and learner 9 we are wearing glasses.

Learners: Laughing.

Learner 9: Sothini yini iATP? (*What will we say ATP is?)*

Jade: Ay'nawe uzobona, uyibuke ukuthi kwenzakalani. *(you'll see, just look at it and see what is going on)*

Learners: *Mumbling*.

Jade: I think there is two minutes left.

Learners: *Mumbling.*

Jade: Huh khona obhal'iquestion *(there's someone that's writing a question)*? Khon'obhal'iquestion? *(there's someone who's writing a question?)…inaudible…*ayaphi amaquestions? *(why are you writing down the questions?)* Ayaphi amaquestions? *(why are you writing down questions?)* Uh alright, before we start, I don't know what the questions are, but I need you to try and label first before (pedagogical knowledge)-cPCK.. we go there. And then we will remove those eh wrong labels if that's the case…*Inaudible*…yes come. Yeh? Niphakamise nini? *(when did you raise your hands?)*

Learners: *Inaudible.*

Jade: Alright let us listen.

Learner 1: So, everyone, according to me uh we at first we have the requirements for well photo photosynthesis to occur. One of, two of the requirements for photosynthesis to occur, so number one is uh radiant energy, this is A. OK, OK, firstly we have OK three requirements for not three, actually excluding chlorophyll OK we have radiant energy, we have water, and we have carbon dioxide. The reason why I said this one is sunlight is because uh I can say that this one is CO_2 because it comes in in the second phase which is light uh light independent phase (pedagogical knowledge)-**ePCK.**

Jade: Maybe write also what are the phases.

Learner 1: Oh OK.

Jade: Identify the phases.

Learner 1: Firstly, we have our light dependent phase or rather, the light phase. Uh this is our light phase which is number one and this number two is our light independent stage or phase or rather the dark phase. So, yah, so the reason why I say this one is the light because we know….(pedagogical knowledge)-**ePCK.**

Jade: Others talking, it's a weekend. You woke up to come here, not the other way round. No one woke you up. Yes (pedagogical knowledge)-**ePCK.**

Learner 1: Uh because we know that of the three requirements of um uh photosynthesis only carbon dioxide only comes in during the dark phase. So that I why I say this one is carbon dioxide, this one is light, and this is water H_2O. so, another reason (pedagogical knowledge)-**ePCK.**

Jade: Uh wait! Wait!

Learner 1: Another reason why I say this one is H_2O is because we can see well the colours. This one is blue right and this one I say its H_2O because eventually after phase one uh one of its elements, akere its hydrogen and oxygen. One of the elements which are well blue I guess uh uh is well after being separated is represented as blue here. So, I just guessed, well blue after the phase. And this one, and this one after the first phase will be the oxygen which is released into the atmosphere (pedagogical knowledge)-**ePCK.**

Learners: Ma'am are we using colours in our exams?

Learners 19: Laughing.

Jade: No, listen, it has nothing to do with the colour. She just decided on the colour because it works for her, but it has nothing to do with the colour. Alright now please mark the whole activity. I need you to start with 'A' so that you can see whether your labels are right or sort of incorrect. OK, what is the first, the question? And then read, ask them they will answer you.

Learner 1: It says uh identify the phases labelled as phase 1 and phase 2. Learner 22 (pedagogical knowledge)-**ePCK.**

Learner 22: Phase 1 is the light phase and phase 2 is the dark phase.

Jade: OK, we can go on. That is correct (pedagogical knowledge)-**ePCK.**

Learner 1: Uh and 'B' says provide the two raw materi materials labelled 'A' and 'B' (pedagogical knowledge)-**ePCK.**

Jade: Raw materials labelled 'A' and 'B'. What is 'A'? (pedagogical knowledge)- **cPCK** ...It says raw materials.

Learner 23: 'A' is a radiant energy or sunlight.

Jade: Yah.

Learner 23: Then 'B' is water.

Learner 19: Number one yi *(it's)* carbon dioxide.

Learner 1: This one? Is carbon dioxe, yah

Learner 19: Ey'two yi *(two of them are)* radiant energy.

Learner 1: So, what's this one? OK.

Learners: *Mumbling.*

Jade: No one is wrong so far until we see the answers.

Learner 1: But I think he is wrong because we don't see the role of carbon dioxide in the first phase, it only comes in in the second phase. Hence this one is radiant energy and uh water (pedagogical knowledge)-**ePCK.**

Learner 19: So, Ma'am ianswer yi yi radiant energy?...

Jade: Asazi *(we don't know)* honestly.

Learner 1: Its radiant energy and water.

Jade: OK, let us go on, let us go on we'll come back to it. Go on Ma'am, 'C'?

Learner 1: Uh 'C' says name the by-product labelled as 'C'.(pedagogical knowledge)-**ePCK.**

Learners: Oxygen.

Learner 1: Oxygen, OK, and 'D' says uh which substance labelled as 'D' is essential for photosynthesis? (pedagogical knowledge)-**ePCK.**

Learners: Carbon dioxide.

Learner 1: Uh okay, 'E', name the product 'E'…

Jade: Uh uh learner 7 and your group there.

Learner 1: Name the product 'E' that is produced during phase 2 (pedagogical knowledge)-**ePCK.**

Learners: Glucose.

Learner 1: OK um in what form, in what from is 'E' stored in plants? (pedagogical knowledge)-**ePCK.**

Learners: Starch.

Learner 1: Yes, so uh describe the role of raw material labelled 'A'.

Learners: Eish, e saran, hectic…*inaudible*…

Learner 1: Hence, exactly, hence I used the colour thing because this one wa…OK I said that already. So, um its useful. Photolysis which is the separation of this molecule called H_2O into a very energised hydrogen atom and its um um oxygen gas which will be released into the atmosphere (pedagogical knowledge)-**ePCK.**

Learners: Nice.

Jade: Thank you, next slide please. Check now if your answers were right. Check if your answers were right. Thank you Ma'am. OK, yes, I think this is what you said was the light phase, dark phase, radiant energy arg, water, eh oxygen. I I think this was all right.

Learners: Yes.

Jade: Right?

Learners: Yes.

Jade: OK we can move on. I want us to take a break but before we take a break let us do this. Eh this requires a cell phone. Oh anikaqedi *(you are not done)*.

Learners: It requires data?.

Jade: Yes.

Learners: As'nalo *(we don't have it)*.

Jade: Why ningenalo *(why don't you have it)*?

Jade and learners: *Inaudible.*

Jade: Eh alright, listen. Yes definitely we are going to do this as group work cause not everyone has a cell phone (pedagogical knowledge)-**pPCK.**

Jade and learners: *Inaudible.*

Jade: Alright, so I am going to hotspot, Ma'am will hot spot a few that side and then I'll hotspot a few also this side. I think group work will also work better. OK, so whoever you're working with in a row maybe two four groups in a row, I don't know. So, this you need a hotspot come and get it. Eh if I see someone busy on YouTube using my data (pedagogical knowledge)-**pPCK.**

Jade and learners: *Inaudible.*

APPENDIX 9: Lesson Observational Transcript from school 1 for lesson 2.

Researcher: OK uh, good morning once more.

Learners: Good morning.

Researcher: So now we are going to do just another lesson for starch test neh. Remember when we were defining photosynthesis, we said it's what? (pedagogical knowledge)-**cPCK**

Learners: starch

Researcher: uh Uh, Photosynthesis, how do you define the entire process? (pedagogical knowledge)-**cPCK**

Learners: *inaudible*

Researcher: OK, let's raise up our hands neh, OK? Yes.

Learner 1: It's a chemical process whereby plants synthesise organic compounds like glucose…*inaudible*… such as carbon dioxide in the presence of radiant energy…*inaudible* (content knowledge)-**cPCK.**

Researcher: Right, so photosynthesis is a process whereby plants use the radiant energy to manufacture glucose neh. (content knowledge)-**pPCK.**

Learners: Yes.

Researcher: And you know that that glucose will be stored in the form of what starch. So now we are going to do how do we test for starch in a leaf neh. Okay, So the objectives of this lesson you should be able to list the materials and the reagents that are needed to test for starch neh, like your apparatus that you will need. And then you will need to know the significance of each and every step, and you need to uh relate the presence of starch of in the leaf production in relation to uh the colours neh, because there will be an… will involve the colours neh, OK. And then now you need to be able to. Yeah, I've already mentioned this. So, these are the apparatus, right? This is? (pedagogical knowledge)-**cPCK**

Learners: Iodine solution (knowledge of the learners)-**ePCK**

Researcher: What is it? What is an iodine solution? Yeah. Please raise up your hands. What is an iodine solution? Yes. (pedagogical knowledge)-**cPCK**

Learner 2: It's a tester (knowledge of the learners)-**ePCK**

Researcher: It's a reagent neh, yes. It's a reagent. So, the iodine solution is a reagent. Yeah, it's the agent that we used to do what to test for starch. It tells us whether starch is present or absent. (content knowledge)-**pPCK** So, do you know the colour of the iodine solution? (pedagogical knowledge)-**cPCK**

Learners: yes

Researcher: What colour is the iodine solution? (pedagogical knowledge)-**cPCK**

Learners: Brown (knowledge of the learners)-**ePCK**

Researcher: Reddish brown. So, the colour its reddish brown. So, when you test for starch, you are necessarily looking at the iodine solution. You observe the iodine solution if whether it's going to change from its original colour and its original colour, it's the reddish brown if it does not change from its original colour. Then that should be an indication that starch is absent, but if it changes from this original colour to a different colour than you know that the starch is present (content knowledge)-**pPCK** OK, So what is this? What do you call this?. It's a what? (pedagogical knowledge)-**cPCK** Someone mentioned it somewhere here.

Learners: It's a dropper (knowledge of the learners t)-**ePCK**

Researcher: It's a dropper neh (pedagogical knowledge)-**ePCK**. What would you use that? (pedagogical knowledge)-**cPCK** OK.

Learners: *Inaudible*

Researcher: Okay, Alright, So what do you think you use the dropper for? What do you think you use the dropper for? (pedagogical knowledge)-**cPCK**

Learner 3: To measure.

Learner 1: To drop the iodine solution in to the plant leaf (knowledge of the learners)-**ePCK**

Researcher: I mean, you see, look at this container. You can't necessarily use a spoon or anything neh. So, you take this dropper. You you just uh it's like you extract the iodine solution neh. And when you extract the iodine solution you're going to drop it on top of the leaf (content knowledge)-**pPCK** What is this? (pedagogical knowledge)-**cPCK**

Learners: Bunsen burner (knowledge of the learners)-**ePCK**

Researcher: Bunsen burner neh (pedagogical knowledge)-**ePCK**, yes so this is a….

Learner 4: Burner?

Researcher: yes, Bunsen burner, Bunsen burner. So, so someone is saying is this not the candle? (pedagogical knowledge)-**cPCK**

Learners: No

Researcher: No neh, so this, yah this Bunsen burner this one is the one that you connect to a gas neh. Yeah, but if you don't have this one, you can substitute this one with the manual one neh. So, the manual you have to use a spirit or a sanitizer to start the the fire neh, (content knowledge)-**pPCK** OK, yes. Then what is this? (pedagogical knowledge)-**cPCK**

Learners: It's a beaker (knowledge of the learners)-**ePCK**

Researcher: This is a? (pedagogical knowledge)-**cPCK**

Learners: A beaker

Researcher: OK, girls, what is this? (pedagogical knowledge)-**cPCK**

Girls: A tweezer (knowledge of the learners)-**ePCK**

Researcher: A tweezer neh. (pedagogical knowledge)-**ePCK**

Learners: *'Laughing'*

Researcher: In our everyday life, we use the tweezer to do what? (pedagogical knowledge)-**cPCK**

Girls: Nails, to fix your eyebrows (knowledge of the learners)-**ePCK**

Researcher: But yeah, I mean the leaf does not have an eyebrow. But anyways, we'll use this tweezer to hold the leaf. So, this is a tweezer, yes it's a tweezer, the normal one. The one that you see. What is this? (pedagogical knowledge)-**cPCK**

Learners: A test tube (knowledge of the learners)-**ePCK**

Researcher: This is a test tube neh, (pedagogical knowledge)-**ePCK** yes. OK, what is this? (pedagogical knowledge)-**cPCK**

Learner 5: Ey angiyazi *(I don't know it).*

Researcher: It's a test tube holder neh. This is what you used to hold this. Especially when it's when it's hot neh. (content knowledge)-**pPCK** Okay guys. Uh one classroom.

Learners: Ethanol (knowledge of the learners)-**ePCK**

Researcher: Ethanol neh, this one is an ethanol (pedagogical knowledge)-**ePCK**. What is the everyday name for ethanol? (pedagogical knowledge)-**cPCK**

Learners: Alcohol (knowledge of the learners)-**ePCK**

Researcher: Alcohol. Not the alcohol that people drink. This one we don't drink this one neh. (content knowledge)-**pPCK.**

Learner 4 and 6: What will happen when you drink it? (knowledge of the learners)-**ePCK**

Researcher: You don't wanna know.

Learner 4 and 6: We just wanna know Ma'am. Ey Ntwana ayikho le *(ey'friend there's no way)*. Ayy…

Researcher: Right. What is… OK, there's two things here neh. There is this. And there's one on top neh. OK, what is this on top? (pedagogical knowledge)-**cPCK**

Learners: It's a soya gauze (knowledge of the learners)-**ePCK**

Researcher: It's a what? (pedagogical knowledge)-**cPCK**

Learners: Soya gauze (knowledge of the learners)-**ePCK**

Researcher: It's a, it's a gauze neh. Yes

Learners: A gauze? (knowledge of the learners)-**ePCK**

Researcher: Yah, it's a wire gauze like. What?, you will use it to as a as a stand for your whatever you put on top. Yes. And then what is this? (pedagogical knowledge)-**cPCK** ..The one at the bottom with three legs.

Learner 2: What are apparatus? (knowledge of the learners)-**ePCK**

Researcher: Apparatus are the material that you're going to be using whatever. Whatever we've been labelling, those are the apparatus for this experiment (content knowledge)-**pPCK.** yes thank you for that (pedagogical knowledge)-**pPCK.**

Learner 2: Materials are the ones that…are they not the tools. It's not the tools (knowledge of the learners)-**ePCK**

Researcher: Remember apparatus now that's a scientific term. So, remember in life sciences that's that word at the end which is science. So, the scientific words that we use and those scientific words they also have the everyday words neh like your normal words, yes, So what is this?

Learners: Tripod stand (knowledge of the learners)-**ePCK**

Researcher: Tripod stand (pedagogical knowledge)-**ePCK** neh. Yeah. So, this is a tripod stand. And then what is this?

Learners: It's a leaf (knowledge of the learners)-**ePCK**

Researcher: This is a leaf. Neh, okay, what about this?

Learners: Water, H2O (knowledge of the learners)-**ePCK**

Researcher: And then what about this one? (pedagogical knowledge)-**cPCK**

Learners: A saucer (knowledge of the learners)-**ePCK**

Researcher: What's that? (pedagogical knowledge)-**cPCK** Okay. Someone is saying isivalo. A lid neh, but here we call it a petri dish.

Learners: Wow, I didn't know (knowledge of the learners)-**ePCK**

Learner 4: *Inaudible.*

Researcher: So, so it's like neh because this is a test for starch that leaf we are gonna do something to that leaf when we're done with whatever we are doing in this leaf, we'll take this leaf, and we will place it there in the petri dish neh. It's like when you're done cooking you dish where? (pedagogical knowledge)-**cPCK**

Learners: In a plate.

Learner 4: Can you eat it Madam? (knowledge of the learners)-**ePCK**

Researcher: No (pedagogical knowledge)-**ePCK**

Researcher: So, uh you know when you enter the lab if you are about to do an experiment, you need to dress a certain way. If you don't dress a certain way, you're not supposed to enter the lab. You are inside the lab because we are not doing a a practical physically. But if we were doing a practical physically, this is what you need to have neh. You need to wear what is. What are this? (pedagogical knowledge)-**cPCK**

Learners: Gloves (knowledge of the learners)-**ePCK**

Researcher: Gloves neh, because you know, as a science learner eh sometimes you work with chemicals neh, so you need to protect your hands neh. Then what is this? (pedagogical knowledge)-**cPCK**

Learners: Googles (knowledge of the learners)-**ePCK**

Researcher: Safety googles neh. Yebo. And then obviously, lab coat. And then can you wear a heel?

Learners: Uh?

Researcher: Amaqhops *(heals)*? (pedagogical knowledge)-**cPCK**

Learners: Yes, No. (knowledge of the learners)-**ePCK**

Researcher: For a practical, no…Remember when you enter the lab neh, safety counts. The first thing that you need to know is that you need to be safe neh. You cannot wear amaqhops *(heals),* you cannot wear ama high heels, you cannot wear open clothes neh. your shoes they need to be closed neh. You can't, ladies, you can't wear a mini skirt neh. You need to wear long trousers or a long skirt.

Learners: Why? (knowledge of the learners)-**ePCK**

Researcher: Like your body has to be covered. If let's say for example you're working with acids. If you drop it or if it spills, it needs to touch your clothes or your shoes before it touches your skin. And in that way it buys you enough time to take off whatever you're wearing, yes. (pedagogical knowledge_-**ePCK**

Learners: What about your neck? What about your skin? (knowledge of the learners)-**ePCK**

Researcher: What about your skin? Then in your skin we can add the mask.

Learners: What about your neck? And the forehead? (knowledge of the learners)-**ePCK**

Researcher: What about the neck? You close, this, this person must close this lab coat up until here. This one *(is being stylish)*_uyaswenka, uyaswenka this one.

Learners: What about the hair? (knowledge of the learners)-**ePCK**

Researcher: Hau, the hair, you can wear a what? (pedagogical knowledge)-**cPCK**

Learners: A helmet (knowledge of the learners)-**ePCK**

Researcher: A helmet? (pedagogical knowledge)-**cPCK** You need a helmet when you're working with uh..

Learners: A bonnet (knowledge of the learners)-**ePCK**

Researcher: You can wear a beanie. Neh, yah. Okay Alright can we move forward?

Learners: Yes

Researcher: Guys let's give this man a name. Let's call him Thabo.

Learners: learner, learner, learner

Researcher: Okay, Now. Eh

Learners: *'Laughing'*

Researcher: Okay, so um with this practical I'll just display this animation video(SAMR) and then I'll take you through it, OK. (pedagogical knowledge)-**cPCK**

Learners: Yes

Researcher: Right, So we are testing a starch where? (pedagogical knowledge)-**cPCK...** in the leaf. So, the first thing that you need to do.

Learner 2: Those at the front can we bend our heads a bit? Bankasiboni konke. The girls at the front can you bend a bit. Just little bit.

Researcher: Okay, are you guys ready? The first thing you need to set up your your experiment neh. Remember everything that we were labelling prior. Uh your tripod stand. You need your tripod stand neh. you will need your beaker. Then you will need your water OK. Then obviously here you will need your Bunsen burner and the fire there (content knowledge)-**pPCK.**. Why? we need to boil that water for about four to five minutes? (pedagogical knowledge)-**cPCK** It depends. Sometimes you can come up, come in with your boiling kettle and boil the water so you can speed up the process neh. OK.

Then now they're telling you. Plug the leaf from a plant. So, when you take a leaf, you take a leaf from a plant neh so you can go outside and find any leaf, any green leaf you take it, you take it inside the beaker. See now they tell you plug a leave from a plant which has been exposed to sunlight and boil it in water for about 5 minutes (content knowledge)-**pPCK.** When you boil it, you do what? (pedagogical knowledge)-**cPCK** ….you soften it and not only are you doing that, you are also stopping the uh anything that is taking place in the leaf, any process is taking place neh, because remember, in the leaf photosynthesis is not the only thing that is taking place. Remember there's cells neh and you know inside your cells there's other processes that are taking place like the protein synthesis in the ribosomes neh. (content knowledge)-**pPCK.** Alright. So, you place your, your leaf where? (pedagogical knowledge)-**cPCK.** in the water neh you start, you start boiling the water neh. Then when you're done boiling the water. Are we boiling the water? (pedagogical knowledge)-**cPCK** ..Yah we are boiling the leaf inside the water.

Learners: Yes

Researcher: yes, so this is our leaf. So, you will remove this leaf and then you will place it where? In the petri dish. You remember the Petri dish neh? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Now its inside neh, okay you see. Here's our petri dish. Here, do you see our? Do you see the tweezer? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: You don't use your hands neh to remove the leaf. You use the tweezer neh. Then you place the leaf here where in the petri dish. OK, okay let's observe. Now you see our Test tube (content knowledge)-**pPCK.**

Learners: Yes.

Researcher: Now you will take the same leaf. You place it in the test tube, then in the test tube we are going to pour the alcohol. Then the same alcohol you are going take it and place it inside that beaker, which has the boiling water neh. (content knowledge)-**pPCK.** Now can anyone tell me why are we placing the leaf inside the alcohol neh in the test tube and then take the test tube and place it inside the beaker, which has the boiling water, why not just boil the alcohol on itself? Why let me take a new hand? Yes. (pedagogical knowledge)-**cPCK**

Learner 7: To extract the chlorophyll from the leaf (knowledge of the learners)-**ePCK**

Researcher: To extract the chlorophyll from the leaf? yes, you use the alcohol to extract the chlorophyll from the leaf. But why not just boil it directly from the fire? Why should we put it inside the water bath? Why? yes. (pedagogical knowledge)-**cPCK**

Learner 8: *Inaudible.*

Researcher: Ehh not really, not really. Someone else? (pedagogical knowledge)-**cPCK** Yes,

Learner 7: *Inaudible.*

Researcher: Because it's a safety precaution neh. If you boil the alcohol directly. What? What are you going to do? You're going to start a fire. Why? Alcohol is flammable. But now if you place it inside a beaker which has water. Now you're using that as a water bath to prevent any flames neh to ensure you don't burn your school neh. Because there's someone who was born yesterday who needs to come and do their grade 11 in this school. Yes. Then someone has already mentioned but we are boiling this leaf inside and alcohol again (content knowledge)-**pPCK**. Why? To remove the what? (pedagogical knowledge)-**cPCK**

Learners: The chlorophyll (knowledge of the learners)-**ePCK**

Researcher: You still remember what is the chlorophyll neh?

Learners: Yes.

Researcher: What is the chlorophyll? (pedagogical knowledge)-**cPCK**

Learners: Green pigment (knowledge of the learners)-**ePCK**

Researcher: Green pigment neh. OK. So now they're telling you again you see. A water bath is used to prevent accidents that may arise from alcohol. Being flammable neh, flammable, put off the flame when the alcohol boils. So, this is just another safety measure that you can do neh. Right. You see here they are showing you as you boil the leaf in the alcohol, it now starts to become what colourless (content knowledge)-**pPCK**, because initially the leaf was what? (pedagogical knowledge)-**cPCK** Was green. So, if you boil it inside the alcohol it becomes colourless neh. Yes. Then when you are done. You are going to remove this leaf from the alcohol, what do you use to remove the leaf from the alcohol? (pedagogical knowledge)-**cPCK**

Learners: The tweezer (knowledge of the learners)-**ePCK**

Researcher: The tweezer. Then you place it where? In the water there. Why do we now place it here in the water? To make it what? (pedagogical knowledge)-**cPCK** To make it soft neh because when you are boiling it inside the alcohol it was stiff neh, but now you place it back to the warm water there it will now become soft neh…*Inaudible.* . (content knowledge)-**pPCK.**

Researcher: Now when you are done, you are going to place your your ohh sorry your your your leaf which is now colourless. It's colourless because it no longer contains a? (pedagogical knowledge)-**cPCK**

Learners: A chlorophyll (knowledge of the learners)-**ePCK**

Researcher: A chlorophyll. You are now going to use your iodine solution. You are going to take this iodine solution and pour it on top of the leaf neh. When you're done doing so, you'll just wait like few minutes and observe what happens (content knowledge)-**pPCK.**

Learner 9: So, like, does the leaf becomes transparent? (knowledge of the learners)-**ePCK**

Researcher: Let's let's let's let's let's let's uh let me finish here neh then I'll get back to you. So, when you pour the iodine solution, we are going to observe neh. Two things can happen neh. OK. Now let me ask you this if. When you.. This is your leaf neh . When you pour your iodine solution in your leaf (content knowledge)-**pPCK.** What colour is the Iodine solution?. (pedagogical knowledge)-**cPCK**

Learners: Orange, brown, reddish brown (knowledge of the learners)-**ePCK**

Researcher: The iodine solution is reddish brown. Now, if you pour the iodine solution on this leaf that is now colourless. And the colour remains the same (content knowledge)-**pPCK.** What does that tell you? (pedagogical knowledge)-**cPCK**

Learners: No starch (knowledge of the learners)-**ePCK**

Researcher: No starch neh. but if you pour the iodine solution in that colourless leaf and the iodi… and the iodine solution changes from reddish brown to blue black (content knowledge)-**pPCK**., what does that indicate? (pedagogical knowledge)-**cPCK**

Learners: The starch (knowledge of the learners)-**ePCK**

Researcher: The starch neh. So, if the starch is present, what does that tell you? (pedagogical knowledge)-**cPCK**

Learners: Photosynthesis has taken place (knowledge of the learners)-**ePCK**

Researcher: Photosynthesis has taken place neh. OK. So, can you move on re-explain this thing now? (pedagogical knowledge)-**cPCK** But now we are using the diagram(SAMR) neh, yes.

Learner 9: So, it's only the iodine solution that can be used for starch? (knowledge of the learners)-**ePCK**

Researcher: It's only the solution that can be used for starch neh, yes, so yes.

Learner 10: *Inaudible.*

Researcher: With a chlorophyll because if if if you don't do all those processes neh, the reagent will not be able to react with the with what's inside the leaf. So, we that's why we have to go over everything neh. If now you can take the leaf, see the leaf from the tree, then you place it here, then you pour the iodine solution nothing is going to happen neh yes. So, the first thing that you do, you set up neh, you have your tripod stand. You have your Bunsen banner. You see, I told you, if you don't have a Bunsen burner, you can substitute and use the manual one way of going to use your spirit or your sanitizer. Neh, Yes. And then you have your, your boiling water. You boil your leaf for few minutes. When you are done boiling the leaf for few minutes. What are you going to do? You remove the leaf (content knowledge)-**pPCK.**. Then afterwards what do you do? (pedagogical knowledge)-**cPCK**

Learners: You put it in the test tube with the alcohol (knowledge of the learners)-**ePCK**

Researcher: You put it in the test tube neh. What's in the test tube? (pedagogical knowledge)-**cPCK**

Learners: Alcohol (knowledge of the learners)-**ePCK**

Researcher: Alcohol neh (pedagogical knowledge)-**ePCK** Right, when you are done what do you do next? (pedagogical knowledge)-**cPCK**

Learners: You put it inside the water (knowledge of the learners)-**ePCK**

Researcher: You take the test tube you put it inside the water. Why do you put the test tube inside the body water? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: To prevent, prevent, uh prevent, prevent uh accidents such as fire. So, you boil it in the water bath (content knowledge)-**pPCK.**, so you boil the, boil it in the? Yes water bath. To prevent what? (pedagogical knowledge)-**cPCK**

Learners: Fire (knowledge of the learners)-**ePCK**

Researcher: To prevent fire. Yes, we call it a water bath neh because we are not boiling it directly, but we are now placing it inside the water, alright (content knowledge)-**pPCK**. Then when you're done what do you do when you're done boiling it here? What happens first as you boil the leaf? What happens to the leaf? (pedagogical knowledge)-**cPCK**

Learners: It becomes colourless (knowledge of the learners)-**ePCK**

Researcher: It becomes what? (pedagogical knowledge)-**cPCK**

Learners: It becomes colourless (knowledge of the learners)-**ePCK**

Researcher: It becomes colourless neh. (pedagogical knowledge)-**ePCK**

Learners: Yes.

Researcher: It becomes colourless neh. The leaf will now become colourless. Why is it now colourless? Because the chlorophyll. You're removing the chlorophyll neh. So, when you do this you remove the chlorophyll (content knowledge)-**pPCK.**. Right, then what's the next thing that you're going to do? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: We put it in the water. To make it what? (pedagogical knowledge)-**cPCK**

Learners: Soft.

Researcher: To make it soft neh, right (pedagogical knowledge)-**ePCK**. Then afterwards, what do you do? (pedagogical knowledge)-**cPCK**

Learners: You remove it (knowledge of the learners)-**ePCK**

Researcher: You remove it you place it in the petri dish neh (pedagogical knowledge)-**ePCK**. Then what do you use to extract the iodine solution? (pedagogical knowledge)-**cPCK**

Learners: A dropper (knowledge of the learners)-**ePCK**

Researcher: A dropper neh, so you use the dropper to extract the iodine solution, and you pour it in the leaf neh, right (content knowledge)-**pPCK**. Now can you see, if there is no starch what colour will the iodine solution be there in the leaf? (pedagogical knowledge)-**cPCK**

Learners: Reddish brown (knowledge of the learners)-**ePCK**

Researcher: It become reddish brown neh. And then if there is a starch present (pedagogical knowledge)-**ePCK**. What tells you that starch is present? (pedagogical knowledge)-**cPCK**

Learners: The blue black (knowledge of the learners)-**ePCK**

Researcher: The blue black neh. When there is a colour change neh. So yes, when there is a colour change from reddish brown to blue black (content knowledge)-**pPCK.**neh. Is it clear? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: We are moving forward neh.

Learners: Yes

Researcher: Okay. Right now, we are. We are going to have two activities next. The first one is to test whether you were listening. Then the second one, it's where you will be making a lot of noise neh.(assessment knowledge)-**cPCK**. All right, can you see?

Learners: Yes

Researcher: Alright, it's. One. how many marks is there? (pedagogical knowledge)-**cPCK**

Learners: one

Researcher: The total It's 11 marks neh and as a life sciences learner you know 1 mark one minute neh. So, you have 11 minutes, which starts now (assessment knowledge)- **cPCK.**

Learners: *Inaudible.*

Researcher: Do not copy the questions. You only write the answers. Now the first question says why was the leaf initially put in a beaker of boiling water? Why? (pedagogical knowledge)-**cPCK** Mmm, yes.

Learner 10: To soften the leaf (knowledge of the learners)-**ePCK**

Researcher: Is it only to soften the leaf? What else? (pedagogical knowledge)-**cPCK**

Learner 11: To stop the processes from taking place in the leaf (knowledge of the learners)-**ePCK**

Researcher: To stop any processes that are occurring in the leaf neh. Cause there's other processes taking place in the leaf neh (content knowledge)-**pPCK.**

Learners: Yes.

Researcher: So, when you boil it you stop all the activities that are taking place in the leaf (content knowledge)-**pPCK.** Are you okay with that? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Then the second one, why was the leaf boiled in alcohol? Why? Why? (pedagogical knowledge)-**cPCK** Yes.

Learner 12: To extract Chlorophyll (knowledge of the learners)-**ePCK**

Researcher: To what? To remove neh. To remove what? (pedagogical knowledge)-**cPCK** Chlorophyll neh.

Learners: Yes.

Researcher: So, you need to boil the leaf so that we can remove the chlorophyll neh. (content knowledge)-**pPCK.**

Learner 2: I'm so sorry ma'am before you continue…*Inaudible*…(knowledge of the learners)-**ePCK**

Researcher: *Inaudible*…And then, guys come back. Why was the test tube with boiling wa…uh boiling alcohol neh placed inside the class beaker with boiling water? Why can we can

I get a different hand or just pick any one randomly? (pedagogical knowledge)-**cPCK** Yes, why yes.

Learner 12: To prevent fires.

Researcher: For safety measures to prevent fire hazard neh. (content knowledge)-**pPCK.** Yah so…

Learners: Yes.

Researcher: To prevent.

Learners: Fires (knowledge of the learners)-**ePCK**

Researcher: Fires? hehey ai eh eh. To prevent hazards such as what? (pedagogical knowledge)-**cPCK**

Learners: Fire.

Researcher: Such as fire neh. (pedagogical knowledge)-**ePCK** Yes, OK now which colour change is observed? (pedagogical knowledge)-**cPCK** Now guys when you speak about the colour change. I want you to know which one is referred to neh cause the issue about the colour change will keep on popping. So, when you when you are writting to your final exam it's gonna be there. They're not referring to the colour change of the leaf. They are referring to the colour change of the iodine solution (content knowledge)-**pPCK.**

Learners: Huhh.

Researcher: Cause the leaf yes, we know it's gonna move from green to colourless neh. So, they are referring to the one that is taking place very pour in the iodine solution what's the colour change. So, can you speak about the colour change then? (pedagogical knowledge)-**cPCK** Yes.

Learner 4: From orange colour of the iodine solution to a blue black colour.

Researcher: So, the colour change will be from? From reddish brown to what? (pedagogical knowledge)-**cPCK**

Learners: Blue black. Starch is present (knowledge of the learners)-**ePCK**

Researcher: Yes neh. OK and then now they say describe the results. Can I can I show you ? Theres two things that they are more likely to ask you. It's either they ask you to describe the results, or they ask you about conclusion neh. When they speak about the results. This is where you speak about the colour change neh. When you speak about the conclusion, then that's when you will speak about it. Now tells me that touch is present or absent. If they say results don't say starch is absent because photosynthesis did not take place, that's the conclusion. Results it's what you see after you were doing something neh. When you pour in the the iodine solution in that leaf you see that there is a colour change from reddish brown to blue black. Now that those are the results neh. But now when you when you when you bring it back to conclusion. Now you will say the colour change indicates that starch is present, meaning that photosynthesis has taken place. Are we clear there? There's a hand there. . (content knowledge)-**pPCK.**

Learner 2: I'm so sorry Ma'am uh. When I did that question…*inaudible*…whether the test, the results are positive or negative. Is that not what we are supposed to write? (knowledge of the learners)-**ePCK**

Researcher: So, when you say the results are positive or negative what does it mean? (pedagogical knowledge)-**cPCK**

Learner 2: Positive means starch was produced (knowledge of the learners)-**ePCK**

Researcher: Now the issue neh with uh life sciences, they want visible evidence. See when you speak about something visible, something you see with your eyes, you see the colour change neh. But you don't see the positive or the negative. It's something that you know. That if it's blue black, that means it's positive. Are we clear on that one? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Good question neh (pedagogical knowledge)-**pPCK**. Alright. Right down the word or chemical equation for photosynthesis. I need someone to come and write the chemical equation neh. Who's coming to write the chemical equation? Okay you are writing the chemical equation neh.

Learners: Applauding learner 4 (knowledge of the learners)-**ePCK**

Learner 4: *(writing the chemical equation on the smartboard)* iyajema (its pausing) lento (knowledge of the learners)-**ePCK**

Researcher: Clean neh. Help help help. What to do now? (pedagogical knowledge)-**cPCK**

Learners: Iyajema lento *(this thing is pausing)* (knowledge of the learners)-**ePCK**

Researcher: Trust the process.

Learner 2: There's nothing wrong with that continue (knowledge of the learners)-**ePCK**

Learner 12: Qhubeka wena boy. Ukuleft. *(continue boy, you're on left)* (knowledge of the learners)-**ePCK**

Learners: Yes, ai yebo.

Researcher and learners: Yes $C6H12O6$ plus $O2$ (knowledge of the learners)-**ePCK**

Researcher: You can write this with your eyes closed. Is this correct? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: So obviously you can translate this into words neh. So, the chemical equation, the word equation will be? (pedagogical knowledge)-**cPCK**

Learners: Carbon dioxide, water, plus, chlorophyll, enzymes, glucose and oxygen (knowledge of the learners)-**ePCK**

Researcher: And oxygen neh.

Learners: Yes.

Researcher: Are we fine with that one? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Alright, so we need someone to come here forward and do a timer for us.

Learners: A timer?

Researcher: Yah, time, time, nako, nako.

Learner 12: Awumyekele boy *(leave him boy).*

Researcher: 30 seconds.

Learners: Nangu u30 lapho *(here is 30).*

Researcher and learners: That's 30 minutes. Sifuna ama *(we want)* seconds. *Inaudible…*

Learner 12: Shisa madoda. Qalenye. Awus'stop(hanga) lesi esiphansi. *(you go boy,. Start over. You didn't stop the one at the bottom* (knowledge of the learners)-**ePCK**

Learner 2: Hhayi ngizosi stop(ha). Obviously ngiqala la *(I'll stop it. Obviously I'm starting here)….inaudible* (knowledge of the learners)-**ePCK**

Learner13: Yicofe ivuleke yonke kaloku *(press it so you can open all of it)* (knowledge of the learners)-**ePCK**

Learner 2: Eh hhayi. Sekazoyivula uMadam *(Madam will open it)* (knowledge of the learners)-**ePCK**

Researcher: Alright. Let's go back to our PowerPoint. Let's see if you know your words. Let's see if you know your words.

Learners: Words? Your words?

Researcher: Yah. Your your key words, your biological terms neh.

Learners: *(learners clapping)* Ohho…okay (knowledge of the learners)-**ePCK**

Researcher: Right, let's start the time. Okay I will start the time (pedagogical knowledge)-cPCK, and I will go back to the…

Jade: Izokhala from the opposite side neh. Time. Iizokhala ngale. *(it will ring on the opposite side. It will ring on the other side)* (knowledge of the learners)-**ePCK**

Researcher: Yah, from the background. Are you ready? Close your books, close your books. No copying. Close or books, close your books.

Learners: *Inaudible.*

Researcher: Ahh vali ingcwadi *(close the book).* Are you ready? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Alright, first word. De… define it.

Learners: *Inaudible.*

Researcher: Okay.

Learners: Stored glucose in the leaf (knowledge of the learners)-**ePCK**

Researcher: Stored glucose in the leaf neh.

Learner 4: Madam.

Researcher: Yes.

Learner 4: It's a by-product released for photosynthesis (knowledge of the learners)-**ePCK**

Researcher: By-product for photosynthesis. Anyone else? (pedagogical knowledge)-**pPCK**

Learners: *Inaudible.*

Researcher: Guys you still have more seconds. Anyone else? How how can you how else can you describe the eh eh starch? (pedagogical knowledge)-**cPCK**

Learner 2: Excess glucose (knowledge of the learners)-**ePCK**

Researcher: Excess glucose neh, yes so we know exc… uh time neh. But at least three people they know neh

Learners: *(laughing)* three people they know (knowledge of the learners)-**ePCK**

Researcher: Okay, we gonna move to the next one neh. Your time to shine is coming neh. Right. Iodine solution, iodine solution. I want, yes.

Learner: Used to test for starch. (learning context)-**ePCK**

Researcher: It is what? (pedagogical knowledge)-**cPCK**

Learner: Used to test for starch.

Researcher: Used to test for starch(pedagogical knowledge)-**ePCK**. Someone else? (pedagogical knowledge)-**pPCK**

Learner: It is a reagent.

Researcher: A reagent used to test for starch (pedagogical knowledge)-**ePCK**. Anyone else? (pedagogical knowledge)-**pPCK**

Learner: It is reddish brown in colour.

Researcher: It is reddish brown in colour (pedagogical knowledge)-**ePCK**. Do you have anything else? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: You can't think under pressure?

Learners: No.

Learner: You use a dropper to extract it.

Researcher: You use a dropper to extract the iodine solution (content knowledge)-**pPCK.** Time, your time is coming to shine don't worry. Time for you to shine is coming right. Be ready. Alright, Uh obvious.

Learners: Obvious.

Researcher: Sugar, someone is saying sugar.

Learners: A by-product.

Researcher: It's a carbohydrate, yes. Anyone else? (pedagogical knowledge)-**pPCK**

Learners: Organic compound, energy.

Researcher: Energy neh. Yes. Product of photosynthesis. What else can you say? (pedagogical knowledge)-**cPCK**

Learner: It's a by-product of.

Researcher: It's a by-product (pedagogical knowledge)-**ePCK**. What else? Uh, time neh. But things are looking good neh. Yah its better than nothing. Right, new word. Chlorophyll, yes. Eh guys.

Learners: Pigment.

Researcher: Green pigment (pedagogical knowledge)-**ePCK**. What else? Yes. (pedagogical knowledge)-**cPCK**

Learner: *Inaudible.*

Researcher: It's a pigment. Yes. Uh guys can we please raise up our hands neh so that everyone can have an opportunity. Yes.

Learners: Sunlight (knowledge of the learners)-**ePCK**

Researcher: Yes, traps? (pedagogical knowledge)-**cPCK**

Learners: Sunlight (knowledge of the learners)-**ePCK**

Researcher: Traps sunlight ne (pedagogical knowledge)-**ePCK**, yes.

Learner: Found in the chloroplast (knowledge of the learners)-**ePCK**

Researcher: Found in the chloroplast good, yes.

Learner: Found in the grana (knowledge of the learners)-**ePCK**

Researcher: Found in the grana, yes. Uh

Learners: Time to shine (knowledge of the learners)-**ePCK**

Researcher: Its coming neh…

Learners: Its coming.

Researcher: OK. You breathe it in. What else? (pedagogical knowledge)-**cPCK**

Learner: It is used; it is the by-product for phase one.

Researcher: It is the by-product during the phase neh. The phase one is the? (pedagogical knowledge)-**cPCK**

Researcher and the learners: Light phase.

Researcher: Yes, okay.

Learner: By-product of photosynthesis (knowledge of the learners)-**ePCK**

Researcher: By-product of photosynthesis.

Learner: Element number 8 (knowledge of the learners)-**ePCK**

Researcher: Element number 8 in the periodic table. Uh time. It's okay, it's okay, hey, are you ready?.(content knowledge)-**cPCK**

Learners: Yes.

Researcher: Alright.

Learners: Phosphorylation (knowledge of the learners)-**ePCK**

Researcher: Phosphorylation (pedagogical knowledge)-**ePCK** let's see. Yes, yes.

Learner: To break down water and oxygen. (knowledge of the learners) -**ePCK**

Learners: No

Researcher: No, no, no, yes. It's a what?

Learner: It's a formation of ATP (knowledge of the learners)-**ePCK**

Researcher: It's a formation of ATP. How do you form it? How do you form it? How do you form it? (pedagogical knowledge)-**cPCK**

Learners: Uh the timer is up (knowledge of the learners)-**ePCK**

Researcher: Uh okay guys.

Learners: Uh time to shine (knowledge of the learners)-**ePCK**

Researcher: Let me shine neh. You form it by combining what? ADP and P. Adenosine diphosphate with a phosphate. To give you ATP. Right. (pedagogical knowledge)- **cPCK**

Learners: Time to shine (knowledge of the learners)-**ePCK**

Researcher: Time to shine, time to shine.

Learners: Time to shine. Chloroplast (knowledge of the learners) -**ePCK**

Researcher: Chloroplast (pedagogical knowledge)-**ePCK**, uh come on, come on. Yes.

Learners: Where photosynthesis take place (knowledge of the learners)-**ePCK**

Researcher: Where photosynthesis takes place. Yes. What else? (pedagogical knowledge)-**cPCK**

Learners: Organelle (knowledge of the learners)-**ePCK**

Researcher: Organelle neh (pedagogical knowledge)-**ePCK**. Yes. Do you find this organelle in animals? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: You only find it where? (pedagogical knowledge)-**cPCK**

Learners: In plants (knowledge of the learners)-**ePCK**

Researcher: Yes, what else can you say about chloroplast? (pedagogical knowledge)-**cPCK** Yes.

Learners: *Inaudible.*

Researcher: Contains a granum, yes what else? (pedagogical knowledge)-**cPCK** Oh time.

Learners: Time to shine.

Researcher: Okay time to shine, time to shine.

Learners: Radiant energy (knowledge of the learners)-**ePCK**

Researcher: Radiant energy. (pedagogical knowledge)-**ePCK**

Learners: Sunlight (knowledge of the learners)-**ePCK**

Researcher: Sunlight. The what? (pedagogical knowledge)-**cPCK**

Learner 2: Radiation from the sun (knowledge of the learners)-**ePCK**

Researcher: Radiation from the sun. yes (pedagogical knowledge)-**ePCK**

Learner: Used for photolysis (knowledge of the learners)-**ePCK**

Researcher: Used for photolysis (pedagogical knowledge)-**ePCK**. Yes. Whuu. Yes.

Learner: It is absorbed in the chlorophyll (knowledge of the learners)-**ePCK**

Researcher: It is absorbed in the chlorophyll (pedagogical knowledge)-**ePCK**. Yes, that's good, yes, what else? (pedagogical knowledge)-**cPCK**

Learners: Nothing.

Researcher: Nothing? Oh, you're lucky. Right, let's hope there's more words neh. OK.

Learner: Madam…*inaudible.*

Researcher: Yes. Haaa you're copying wena. Yes. Yes.

Learner: The process of using light to break down the organic something (knowledge of the learners)-**ePCK**

Researcher: Organic something? Organic compounds neh. The process of using light to break down organic compounds. Yes. Photolysis? Can you? Oh time. Alright someone said formation of uh sorry, a process where you break down organic compounds. What organic compounds are you breaking? (pedagogical knowledge)-**cPCK**

Learners: Water.

Researcher: Into what? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible*…suke emabhozeni, aw'suke amabhozeni. *(stay away from the bosses)*

Researcher: Carbon dioxide guys. You don't know? Hhayi, what's going on here? Yes (knowledge of the learners)-**ePCK**

Learner: Siyayi exhale(a) *(we exhale it).*

Researcher: It's a gas you exhale. What else? (pedagogical knowledge)-**cPCK** Yes.

Learners: *Inaudible.*

Researcher: Yah, yes, it's a what? (pedagogical knowledge)-**cPCK**

Learner: Requirement (knowledge of the learners)-**ePCK**

Researcher: Requirement for photosynthesis (pedagogical knowledge)-**ePCK**. Yes.

Learner: It's a by-product in the dark phase (knowledge of the learners)-**ePCK**

Researcher: By-product in the dar..in the light phase neh…(pedagogical knowledge)-**ePCK**

Learners: Dark (knowledge of the learners)-**ePCK**

Researcher: Yes it's a…

Learners: Huhh!

Researcher: No no. Eh, it's a requirement of the dark phase neh. Okay, okay, okay, okay yes.

Learners: Time to shine is over. Yes…*Inaudible.*

Researcher: OK.

Learners: Blue black (knowledge of the learners)-**ePCK**

Researcher: Yes.

Learners: Starch is present (knowledge of the learners)-**ePCK**

Researcher: Uh guys hello, uh uh one class, one class. It's a what? (pedagogical knowledge)-**cPCK**

Learners: It's a colour (knowledge of the learners)-**ePCK**

Researcher and learners: It's a colour that shows that starch is present. Nhe, yes. Neh. Okay, What else?

Learners: It's a colour (knowledge of the learners)-**ePCK**

Researcher: Positive indication that? Yes.

Learners: *Inaudible.*

Researcher: Hhayi liyaphela iclass khululeka.*(don't worry the lesson will be over now)*

Learners: Stroma (knowledge of the learners)-**ePCK**

Researcher: Stroma, it's a site for? (pedagogical knowledge)-**cPCK**

Researcher and learners: Dark phase. Neh, yes, its where dark phase takes place. Yes.

Learner: It has ribosomes (knowledge of the learners)-**ePCK**

Researcher: Yes, it has ribosomes. Yes. (pedagogical knowledge)-**ePCK**

Learner: It's found in the chloroplast (knowledge of the learners)-**ePCK**

Researcher: It's found in the chloroplast (pedagogical knowledge)-**ePCK**. Yes. Going once, going twice. Uh time. OK

Learners: Hhay iyashesha le 30 seconds *(this 30 second is quick)*. It didn't start; it didn't start. It didn't start (knowledge of the learners)-**ePCK**

Researcher: Thank you, yes.

Learners: It's a colour of the iodine solution (knowledge of the learners)-**ePCK**

Researcher and learners: It's a colour of the iodine solution neh. Yes, yes. (pedagogical knowledge)-**ePCK**

Researcher: If you see the this colour it means?

Learners: No starch is present (knowledge of the learners)-**ePCK**

Researcher: No starch is present (pedagogical knowledge)-**ePCK**. If no starch is present it means? (pedagogical knowledge)-**cPCK**

Learners: Photosynthesis did not take place (knowledge of the learners)-**ePCK**

Researcher: Alright.

Learners: Stomata. (learning context)-**ePCK**

Researcher: Stomata. Yes. (pedagogical knowledge)-**ePCK**

Learners: The opening. (learning context)-**ePCK**

Researcher: The opening of what what? (pedagogical knowledge)-**cPCK**

Learners: Leaf (knowledge of the learners)-**ePCK**

Researcher: The opening of the leaf neh, yes. It is surrounded by guard cells.

Learners: Yes.

Researcher: OK, what else? (pedagogical knowledge)-**cPCK**…Yes.

Learner 2: Ma'am, the opening of the leaf where gases are drawn in and drawn out.(knowledge of the learners)-**ePCK**

Researcher: Gases are drawn in and drawn out. What comes in, what comes out?

Learners: *Inaudible.*

Researcher: Grana. Its where the light phase takes place. Yes.

Learners: *Inaudible.*

Researcher: Anyone? It's a group of? (pedagogical knowledge)-**cPCK**

Learner: Thylakoids (knowledge of the learners)-**ePCK**

Researcher: It's a group of lamella, thylakoids neh. Okay, what else? It traps? (pedagogical knowledge)-**cPCK**

Researcher and learners: Sunlight (knowledge of the learners)-**ePCK**

Researcher: Using what? (pedagogical knowledge)-**cPCK**

Researcher and learners: Chlorophyll neh. (knowledge of the learners)-**ePCK**

Researcher: Okay, do we have more words? No…okay done.

APPENDIX 10: Lesson Observational Transcript from school 2 for lesson 1.

Samantha: When you see this what comes to your mind? Okay ubonani *(what do you see)* keh? Ubonani *(what do you see)*? What do you see? What do you see? (pedagogical knowledge)-**cPCK**

Learners: Plants, trees (pedagogical knowledge)-**cPCK**

Samantha: Someone said plants, and then what do you guys know about trees or plants? (pedagogical knowledge)-**cPCK** Oh, sorry, I forgot. Um, OK. Haike, Okay let's do this, Uh…*inaudible*… OK sharp trees or plants. Huh shem ay'funi *(it doesn't want to).*

Learners: Yeah!!!

Samantha: Clearly I'm the problem.

Learners: I'ynzipho *(its nails)*.

Samantha: Yeh?

Learners: I'ynzipho *(its nails)*.

Samantha: I'ynzipho *(its nails)*?

Learners: Yes.

Samantha: Huh!!! So ngifela ukuthi manje ngifuna ukuba muhle *(so, I'm paying for wanting to be beautiful)*?

Learners: Yes.

Samantha: Yew. Okay sharp, trees plants. What do you know about trees and plants ku life sciences? What do trees or plants do for us? (pedagogical knowledge)-**cPCK**

Learner 1: They supply us with oxygen (pedagogical knowledge)-**cPCK**

Samantha: They supply us with oxygen. Huh, eh! Oxygen, (content knowledge)-**pPCK** what else? What else do plants supply us with? (pedagogical knowledge)-**cPCK** Yes learner 1.

Learner 2: They supply us with food (knowledge of the learners)-**ePCK**

Samantha: Mhm! Food? Yes food. So, the food is in what form? (pedagogical knowledge)-**cPCK**

Learner 3: Glucose (knowledge of the learners)-**ePCK**

Samantha: Glucose (pedagogical knowledge)-**pPCK** and then what is the process in which the plants make their own food? (pedagogical knowledge)-**cPCK**

Learners: Photosynthesis (knowledge of the learners)-**ePCK**

Samantha: Photosynthesis (pedagogical knowledge)-**pPCK**, so that is what we will be focusing on today iphotosynthesis. Right, um do you guys still remember what is the definition of photosynthesis? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Learner 4 do you remember what the definition of photosynthesis? Mmm, OK So, what we will be focusing on today, we are here to understand the basic concept of photosynthesis. Ukuthi kahle kahle *(that)* what is photosynthesis? What makes photosynthesis important? And how is it important for ama *(the)* plants and also other organisms like animals. Then know how to define the basic biological terms referring to photosynthesis, right!. You're know…you're here to know how to write the word and the chemical equation for photosynthesis. Angithi there's two equations. There's a word equation which is you have the actual word oxygen, carbon dioxide and then in chemical equation you have the symbols which is O_2 and…(content knowledge)-**pPCK**

Learners: CO_2 (knowledge of the learners)-**ePCK**

Samantha: CO_2. Identify the roles of sunlight, water, chlorophyll and carbon dioxide. These are all the requirements of photosynthesis. So, you need to know what are the roles of sun, what is the role of sunlight? What is the role of water? What is the chlorophyll and carbon dioxide in the entire process of photosynthesis? Then you need to know how to describe phases, the two phases, which is which is the light phase and the dark phase. Then the last point you need to know how to describe the significance. When we use the term significance what comes into your mind? (content knowledge)-**pPCK**

Learner 3: Importance (knowledge of the learners)-**ePCK**

Samantha: Importance. (pedagogical knowledge)-**pPCK** Kanti why nihleba *(why are you whispering)*? Why…*inaudible*…importance right! So, when we look at the term significance we are going to look at the importance of photosynthesis. So, these are the biological terms for photosynthesis. First one is the actual term, photosynthesis. What is photosynthesis? (pedagogical knowledge)-**cPCK**

Learner 3: The process whereby plants make their own food using the sunlight and carbon dioxide (content knowledge)-**cPCK**

Samantha: Yes, it is the process whereby plants make their own food using the sunlight and carbon dioxide (content knowledge)-**pPCK** Okay. So, from this um definition what are the two requirements of photosynthesis? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Samantha: Angizwa *(I can't hear)*?

Learners: Sunlight and carbon dioxide (knowledge of the learners)-**ePCK**

Samantha: Sunlight and carbon dioxide (pedagogical knowledge)-**pPCK**. Right, then right then. Let's go back to the slides. Right, then we have photolysis. What does 'photo' mean? Photo? (pedagogical knowledge)-**cPCK**

Learner 1: To make (content knowledge)-**ePCK**

Samantha: Photo? To make? (pedagogical knowledge)-**pPCK** No. photo? (pedagogical knowledge)-**cPCK**

Learner 2: Means light (knowledge of the learners)-**ePCK**

Samantha: Photo? Yes, photo means light (pedagogical knowledge)-**pPCK**. So, what do you guys think photolysis is? (pedagogical knowledge)-**cPCK**

Learner 3: It's a splitting of water molecules into (knowledge of the learners)-**ePCK** …

Samantha: Into water? It's a splitting of water molecules into hydrogen and oxygen. So, the reason why there's 'photo' there is because the light from the sunlight…*inaudible*…. remember water is a compound right? So, you need energy to make up a compound, you also need energy to split a compound. So, the light from the sunlight is needed to split the water molecules (content knowledge)-**pPCK**. Hello learner 5. Then we have chlorophyll, what does chlorophyll mean? (pedagogical knowledge)-**cPCK**

Learner 3: Green pigment (knowledge of the learners)-**ePCK**

Samantha: The green pigment that is found in what? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Samantha: In what? (pedagogical knowledge)-**cPCK**

Learners: In the leaf (knowledge of the learners)-**ePCK**

Samantha: Where in the leaf? (pedagogical knowledge)-**cPCK**

Learners: In the chloroplast (knowledge of the learners)-**ePCK**

Samantha: Inside of the chloroplast. Yes, and then ichloroplast it is the organelle where photosynthesis does what? (pedagogical knowledge)-**cPCK**

Samantha and the learners: Takes place.

Samantha: Bese *(then)* we have iphosphorylation. Phosphorylation you remember the term from cellular respiration angithi *(right)*? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: It has to do with what? (pedagogical knowledge)-**cPCK**

Learner 4: The formation of ATP (knowledge of the learners)-**ePCK**

Samantha: Formation of? (pedagogical knowledge)-**cPCK**

Learner 4: ATP.

Samantha: The formation of ATP. Then, the ATP eqeda ukukhulunywa uLearner 3 *(what was just said by learner 3)* its adenosine triphosphate (content knowledge)-**pPCK**. It is three phosphates combined which is iATP is known as what? (pedagogical knowledge)-**cPCK**

Learner 3: Energy carrier (knowledge of the learners)-**ePCK**

Samantha: The energy carrier. Then we have iglucose which is the? Glucose is the? (pedagogical knowledge)-**cPCK**

Learner 4: Starch (knowledge of the learners)-**ePCK**

Samantha: Is the? (pedagogical knowledge)-**cPCK**

Learner 3: Starch granule (knowledge of the learners)-**ePCK**

Samantha: Is the starch? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Samantha: Is the what? (pedagogical knowledge)-**cPCK**

Learner 4: Is starch granule (knowledge of the learners)-**ePCK**

Learner 3: By product (knowledge of the learners)-**ePCK**

Samantha: Starch granule? No.

Learner 3: By product (knowledge of the learners)-**ePCK**

Samantha: No, cishe *(almost)*. By product? Of what? Why is the by…so if glucose is the by product what is the main product? (pedagogical knowledge)-**cPCK**

Learner 3: Oxygen (knowledge of the learners)-**ePCK**

Samantha: Oxygen? So kahle kahle *(basically)* so if oxygen is the main product and glucose is the by-product what is the definition for photosynthesis? What is the definition eh learner 6 (pedagogical knowledge)-**pPCK**, you said it first akere *(right)*. What is the definition of photosynthesis? (pedagogical knowledge)-**cPCK**

Learner 6: Process…

Samantha: Whereby? (pedagogical knowledge)-**cPCK**

Learner 6: Plants make their own food (knowledge of the learners)-**ePCK**

Samantha: What is the food? (pedagogical knowledge)-**cPCK**

Learner 6: Glucose (knowledge of the learners)-**ePCK**

Samantha: So, which means that the food is glucose angithi *(right)* (content knowledge)-**pPCK**

Learners: Yes.

Samantha: And then which means that the main product is? (pedagogical knowledge)-**cPCK**

Learners: Glucose (knowledge of the learners)-**ePCK**

Samantha: So, glucose is the main product of photosynthesis. Then we have iNADP which stands for nicotinamide adenine dinucleotide phosphate (content knowledge)-**pPCK**

Learners: iYoh!!

Samantha: Yah heh. NADP it is the carrier that is needed in the process of photosynthesis. So, these are the requirements of photosynthesis (content knowledge)-**pPCK** The first one is? (pedagogical knowledge)-**cPCK**

Learners: Water (knowledge of the learners)-**ePCK**

Samantha: The next one is? (pedagogical knowledge)-**cPCK**

Learners: Sunlight (knowledge of the learners)-**ePCK**

Samantha: And that one is? (pedagogical knowledge)-**cPCK**

Learners: Carbon dioxide (knowledge of the learners)-**ePCK**

Samantha: Which means that in the equation of photosynthesis these three things are going to be on the left side right, they are going to…*inaudible*…because they are the requirements. When something is a requirement it means that it is needed for photosynthesis. And then the products, we have two products (content knowledge)-**pPCK**. Which is? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Samantha: And?

Learners: Glucose (knowledge of the learners)-**ePCK**

Samantha: Ni *(are you)* sure? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Glucose? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Is it not carbohydroxide? (pedagogical knowledge)-**cPCK**

Learners: No, ai yi glucose (knowledge of the learners)-**ePCK**

Samantha: Owo, no I am just confirming. Yes, the products are glucose and oxygen. So, someone said when we showed Iy'hlahla ek'qaleni *(trees in the beginning)* that those were plant right. So, a background about plants, they fall under the kingdom plantae, and they are eukaryotes (content knowledge)-**pPCK**. What is a eukaryote? (pedagogical knowledge)-**cPCK**

Learner 7: Organisms that have a true nucleus. Organisms that have a true nucleus (knowledge of the learners)-**ePCK**

Samantha: Organisms that have a true nucleus are eukaryotes (content knowledge)-**pPCK** What are autotrophs? (pedagogical knowledge)-**cPCK**

Learners: Organisms that can make their own food (knowledge of the learners)-**ePCK**

Samantha: Organisms that make their own food (pedagogical knowledge)-**pPCK**. Konje what is, what are prokaryotes? (pedagogical knowledge)-**cPCK**

Learners: Organisms that do not have a true nucleus (knowledge of the learners)-**ePCK**

Samantha: Organisms that does not have a true nucleus (content knowledge)-**pPCK**. And then what are heterotrophs? (pedagogical knowledge)-**cPCK**

Learners: Organisms that cannot make their own food (knowledge of the learners)-**ePCK**

Samantha: Organisms that cannot make their own food (content knowledge)-**pPCK**. Right, so where exactly in the plant does photosynthesis takes place? (pedagogical knowledge)-**cPCK** It takes place on the leaf, so this is the structure that we di ka grade 10. Which is last year, right? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: We learnt about the epidermis; we learnt about cuticle. Konje what do you guys remember the cuticle? (pedagogical knowledge)-**cPCK**

Learner 3: Waxy.

Samantha: Waxy, and its transparent to allows light to pass pass through right (content knowledge)-**pPCK**

Learner 2: Yes.

Samantha: And then the reason why light should pass through it is because it must reach the palisade mesophyll, which is where we found most of the chloroplast (content knowledge)-

pPCK. Right, and then do you guys remember the difference between the palisade mesophyll and the spongy mesophyll? (pedagogical knowledge)-**cPCK** Mmm. Yes.

Learner 7: A palisade mesophyll contains more chloroplast than the spongy mesophyll. Therefore, the…therefore greater amount of photosynthesis takes place (knowledge of the learners)-**ePCK**

Samantha: Yes, palisade mesophyll is made up of more chloroplasts hence that is where most of photosynthesis takes place, inside the palisade mesophyll. So, yes photosynthesis takes place in the plant, yes it takes place on the leaf (content knowledge)-**pPCK** but where exactly on the leaf? (pedagogical knowledge)-**cPCK** On the palisade mesophyll. And then why is the cuticle there? (pedagogical knowledge)-**cPCK** It is there because it must be transparent to allow light to pass through. Right, then this is the structure of the chloroplast. This is the structure of a chloroplast. So, this one yile *(is)* that you see in our textbooks normally but then in the exams they normally show this one. Then when you guys see the picture niyaxakeka *(you're confused)* and you guys say yini manje le *(what is this?)*. So, this is a microscopic picture(SAMR) of a chloroplast. It is known as ama micrographs. We did a micrographs last year when we were calculating an actual size of a cell (content knowledge)-**pPCK**. Do you remember? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Right! So, the labels of the chloroplast, what makes a chloroplast to be a chloroplast? (pedagogical knowledge)-**cPCK** It has a double membrane, it has a granum, it has thylakoids, it has ribosomes, it has stroma. So, remember at the beginning we said there's two phases (content knowledge)-**pPCK**

Learners: Yes.

Samantha: The dark phase and light phase (content knowledge)-**pPCK**. Do they both take place in the chloroplast? (pedagogical knowledge)-**cPCK**

Learners: No.

Samantha*: (Giving learners a dead stare).*

Learners: Yes.

Samantha: Ngicela niz'thembe *(please trust yourselves)*. Do they both take place in the chloroplast?

Learners: Yes.

Samantha: Sure?

Learners: Yes.

Samantha: Yes, they do take place in the chloroplast. One takes place in the stroma, the other takes place in the grana. Right (content knowledge)-**pPCK**

Learners: Yes.

Samantha: Right, so, the light dependent phase its also known as the light phase (content knowledge)-**pPCK** The light phase, the light-dependent phase of photosynthesis takes place in the what? (pedagogical knowledge)-**cPCK**

Learners: Grana (knowledge of the learners)-**ePCK**

Samantha: So, k'shukuthi *(it means that)* the light-dependent phase takes place here in the grana. Light phase. Right, the light-dependent phase of photosynthesis takes place in the granum of the chloroplast as follows: Remember we talked about um as one of the things we talked about today sathi *(we said)* there's you need to know the role of sunlight, you need to know the role of chlorophyll, the role of carbon dioxide, right, which are the three requirements of photosynthesis. So, this is the picture(SAMR) of the sun right. Badrawer leli vele enijwayele ukulidrawer eprimary *(they are drawing the one that you used to draw at primary)* school…*inaudible*…yes, the sun. so, the sun uh it gives us iradiant energy right. And then the radiant is absorbed by the grana (content knowledge)-**pPCK**. What structure or what is found in the grana that allows for the light to be absorbed? (pedagogical knowledge)-**cPCK**

Learner 3: Chlorophyll (knowledge of the learners)-**ePCK**

Samantha: Chlorophyll. So, the chlorophyll is the one that absorbs, chlorophyll is the one that absorbs the radiant energy from the sun. Then this energy is the one that's needed for, there's this um process that we explained earlier that breaks down the wa…the water molecules. (content knowledge)-**pPCK** What process is that? (pedagogical knowledge)-**cPCK**

Learners: Photolysis (knowledge of the learners)-**ePCK**

Samantha: Photolysis. Right, so step one, um radiant energy absorbed by the chlorophyll that is found in the grans. Step two, water goes into the chloroplast (content knowledge)-**pPCK** What is the part of the leaf where the water enters? (pedagogical knowledge)-**cPCK**

Learner 8: Guard cell (knowledge of the learners)-**ePCK**

Samantha: Mmm? Ama guard cell yes, so, but then there's this tissue that is responsible for absorbing water (content knowledge)-**pPCK**

Learners: Xylem (knowledge of the learners)-**ePCK**

Samantha: The xylem. Sorry, so, what happens is the radiant energy is absorbed uh by the grana and water is also absorbed inside the chloroplast. Then number three that is the water molecule. So, this is a chemical equation for water H_2O right (content knowledge)-**pPCK**. Then what is this process when the water split to H plus ad oxygen. What is it called? (pedagogical knowledge)-**cPCK**

Learners: Photolysis (knowledge of the learners)-**ePCK**

Samantha: Photolysis. So, this here its photolysis. Right, and the at the end what is released from, number 5 what is released? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Samantha: Oxygen. Oxygen will leave through the guard cells which where kwenzeka igaseous exchange *(where gaseous exchange takes place)*. Then last part, ATP is also going to be released. Why? Because there's the energy (content knowledge)-**pPCK** that is lost when the compound it splits nge photolysis also it should be carried on to the next phase. The next phase is the light-independent phase. Which is known as? (pedagogical knowledge)-**cPCK**

Learners: Dark phase (knowledge of the learners)-**ePCK**

Samantha: Dark phase. The light-independent phase of photosynthesis takes place in the stroma of the chloroplast. Let's go back to the stroma. This is where the dark phase takes place. Right, so what happens, the light-independent phase or the dark phase of photosynthesis takes place in the stroma of the chloroplast as follows: we have the next requirement which is carbon dioxide. Carbon dioxide enters via the guard cells and then it combines with the H plus and the ATP (content knowledge)-**pPCK**. Where are these two things coming from? (pedagogical knowledge)-**cPCK**

Learners: The light phase (knowledge of the learners)-**ePCK**

Samantha: The light phase. Which structure does the light phase take place? (pedagogical knowledge)-**cPCK**

Learners: Grana (knowledge of the learners)-**ePCK**

Samantha: The grana. So, the H plus and the ATP they come from the grana. They are the outputs of light phase (content knowledge)-**pPCK**. And then when all of these combine they form the glucose. Which is the sugar, or which is the food that plants make. Then where is this glucose going to be stored? (pedagogical knowledge)-**cPCK**

Learner 9: In the starch (knowledge of the learners)-**ePCK**

Samantha: Thank you (pedagogical knowledge)-**pPCK**, it is going to be stored in the starch granule, and it is going to be stored as starch (content knowledge)-**pPCK**. Are we clear? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Right, so this is summary of what happens in these two phases of photosynthesis. Light phase, the water is split and then it releases what? (pedagogical knowledge)-**cPCK** Oxygen to the by-product of photosynthesis. Then also releases releases hydro… hydrogen and ATP which will be carried on to the phase, dark phase. Then the dark phase, the carbon dioxide is enters into the stroma. Then glucose is released as a main product. So, kahle kahle the reason why photosynthesis takes place is because of this glucose right, this is the food that plants need. Also, this is the food that all other living organisms found in the ecosystem need for survival. Then we have the chemical equation and the word equation. It's carbon dioxide plus water, then in the presence of sun energy and also because we need the chlorophyll to absorb the sun energy we get glucose which is $C_6H_{12}O_6$ plus oxygen (content knowledge)-**pPCK**. Which one is the main productt? (pedagogical knowledge)-**cPCK**

Learners: Glucose (knowledge of the learners)-**ePCK**

Samantha: Which one is the by-product? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Samantha: Right, so this is how photosynthesis takes place. Ma'am is it fine that I call one of the learners to? (knowledge of the learners)-**ePCK** OK. Anyone who's confidence?…*inaudible*…Hau uphi u *(where is)* learner 10? If ulearner 10 bekakhona bekazoza *(if learner 10 was here he'd come)*. Anybody? Learner 8? Learner 3? You're my last hope. OK learner 11 woza Bhuti *(come brother*) (pedagogical knowledge)-**pPCK**

Learner 11: Ma'am kenziwani *(Ma'am what are we doing)* ? (knowledge of the learners) -**ePCK**

Samantha: Nawe uyazi *(you also know).*

Learner 11: Kwenziwani Ma'am *(what are we doing Ma'am)* ? (knowledge of the learners)-**ePCK**

Samantha: Explaina ukuthi kwenzakalani *(explain what is happening here)*. Leaf, cell structure, where does photosynthesis take place? (pedagogical knowledge)-**cPCK** What I was explaining. Yes.

Learner 11: Sanibonani *(Hi)*.

Learners: Yebo.

Learner 11: Oh. So. Yi sunlight le? (knowledge of the learners)-**ePCK**

Samantha: Yes.

Learner 11: So, guys isunlight, eh isunlight izongena ku grana *(the sunlight will enter the grana)* (knowledge of the learners)-**ePCK**

Samantha: Mmm.

Learner 11: And then ku grana that's where iADP ne ne NAT ne NATP is formed (knowledge of the learners)-**ePCK**

Samantha: Learner 11.

Learner 11: Ma'am.

Samantha: Please explain with your understanding, ungafundi ungafundi *(don't read don't read)*. Just explain with your understanding.

Learner 11: So, isunlight meyiqeda ukungena ku grana *(after the sunlight enters the grana)* eh.. (knowledge of the learners)-**ePCK**

Samantha: Mmm?!

Learner 11: Ma'am ngikhohliwe yaz *(Ma'am I forgot)* (knowledge of the learners)-**ePCK**

Samantha: Huh! hlala phansi *(sit down)*. OK, I Will start again cause clearly. Leaf, OK the leaf, right, this is where photosynthesis takes place. The organ where photosynthesis takes place. Right! Then the leaf anatomy they are just showing us how the leaf looks like on the on the inside. That's where we find the spongy mesophyll and the palisade mesophyll, which where is chloroplast in found, right! This is how the chloroplast looks like angithi *(right)* (content knowledge)-**pPCK**

Learners: Yes.

Samantha: In the chloroplast we have the grana, and we have the stroma. The grana is where what take (content knowledge)-**pPCK**, which phase takes place in the grana? (pedagogical knowledge)-**cPCK**

Learners: Light phase (knowledge of the learners)-**ePCK**

Samantha: Light phase (pedagogical knowledge)-**ePCK**. And then in the stroma? (pedagogical knowledge)-**cPCK**

Learners: Dark phase (knowledge of the learners)-**ePCK**

Samantha: Dark phase (pedagogical knowledge)- **ePCK.** Right, so this is a sunlight that is being absorbed into the grana. What substance is found in the grana that allows for the absorption of sunlight? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll (knowledge of the learners)-**ePCK**

Samantha: Chlorophyll (pedagogical knowledge)- **ePCK**, then the chlorophyll absorbs sunlight in the grana. Then that sunlight is going to be used to split the water molecule into hydrogen and oxygen (content knowledge)-**pPCK**. The process where high water molecule is split into hydrogen and oxygen is called? (pedagogical knowledge)-**cPCK**

Learners: Photolysis (knowledge of the learners)-**ePCK**

Samantha: Photolysis (pedagogical knowledge)-**pPCK**. Then after that, what is going to be released released into the atmosphere as by-product? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Samantha: Oxygen. Then the water the hydrogen will be carried on to the stroma which is where the dark phase takes place. In the stroma that is where the carbon dioxide is going to be absorbed into the stroma, is going to combine with the hydrogen molecules using the ATP from the light phase to form glucose. Which is the main product of photosynthesis (content knowledge)-**pPCK** So, that's what's happening here. Right, OK the significance of photosynthesis, how is photosynthe photosynthesis important in the ecosystem? Right, What are you guys seeing here? Should I zoom in or you can see? (pedagogical knowledge)-**cPCK**

Learners: Siyabona *(we can see).*

Learner 12: Fish (knowledge of the learners)-**ePCK**

Samantha: Fish? Fish? Oh, OK there's fish. How do you think the fish benefits from photosynthesis? How does the fish benefit? This…think about the two products, think about the main product of photosynthesis. Not the two main products, the two products. The glucose and oxygen. So, how does the fish benefit? What does it gets? Photosynthesis (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Samantha: Oxygen, because fish also need oxygen right! (content knowledge)-**pPCK**

Learners: Yes.

Samantha: For cellular respiration angithi *(right)* (content knowledge)-**pPCK**

Learners: Yes.

Samantha: OK, what else do you see? (pedagogical knowledge)-**cPCK**

Learner 10: Frog (knowledge of the learners)-**ePCK**

Samantha: Frog, how does the frog benefit from photosynthesis? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Samantha: Oxygen, right? It gets oxygen. What else do you see? (pedagogical knowledge)-**cPCK**

Learners: Food (knowledge of the learners)-**ePCK**

Samantha: Fungi? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Iphi ifungi *(where is fungi)*? (pedagogical knowledge)-**cPCK**

Learners: Ikhona *(its there).*

Samantha: Guys Niyazi *(you know)* ifungi it's an entire. Oh babhale ukuthi *(they wrote)* fungi? Oh damn! Oh OK. How does fungi benefits from photosynthesis? (pedagogical knowledge)-**cPCK** Angisho fungi is not plant.

Learners: Yes.

Samantha: It's a whole kingdom of given organisms (content knowledge)- **pPCK.** So, what do they get from photosynthesis? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Samantha: Oxygen, same response. But it differs here, what is this animal? (pedagogical knowledge)-**cPCK**

Learners: Kangaroo (knowledge of the learners)-**ePCK**

Samantha: Is it a carnivore, herbivore or omnivore? (pedagogical knowledge)-**cPCK**

Learners: It's a herbivore (knowledge of the learners)-**ePCK**

Samantha: It's a herbivore, which means it eats what? (pedagogical knowledge)-**cPCK**

Learners: Plants (knowledge of the learners)-**ePCK**

Samantha: Plants only right? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: So, the kangaroo receives two benefits from photosynthesis. It receives the oxygen and?

Learners: Glucose (knowledge of the learners)-**ePCK**

Samantha: Which is the? (pedagogical knowledge)-**cPCK**

Samantha and the learners: Food.

Samantha: Right, so um there's no chicken here or anything, cow nyana, nothing, OK, So example keh, if there was a cow right, let's say here's the cow here. I can't draw uyazi. If there was a cow right. A cow is grazing and eating grass, grass is a plant which means grass photosynthesizes neh. So, the cow will get um food from the grass and also it will get oxygen from the grass right. And then let's say there's learner 13 sitting under the tree (content knowledge)-**pPCK**

Learners: *(Laughing.)*

Learner 2: Yho ulearner 13 angeke asa athenda *(learner 13 won't attend anymore).* Ngiyaxolisa *(I'm sorry)* leaner 13. Um there's learner 13 sitting under the tree right? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Learner 13 owns the cow right, then learner 13 decides to kill the cow (pedagogical knowledge)-**cPCK**

Learners: Huhh.

Samantha: For food. Right, so um how will learner 13 benefit from iphotosynthesis? In that regard there's a cow, there's also learner 13 sitting under the tree (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Samantha: Ini *(what)*?

Learner 4: Ukudla ne *(food and)* oxygen.

Samantha: Ukudla ne *(food and)* oxygen right (pedagogical knowledge)-**pPCK**. So, basically photosynthesis is the um uh the basic or the main supplier of food. If there was no photosynthesis then we wouldn't have food because cows need the grass, and animals need the cow or learner 13 needs the cow right. So, if there's no cow, learner 13 will not have food and learner 13 cannot eat grass. Learner 13 can you eat grass? (pedagogical knowledge)-**cPCK**

Learner 13: No.

Samantha: Exactly. Oh, konje kune video la *(there's a video here)*. Ma'am where do I press play? (pedagogical knowledge)-**ePCK** Ayinavolume (*it doesn't have volume)*? Right right righ right. What is this? (pedagogical knowledge)-**cPCK**

Learner: Plants.

Samantha: Grass? (pedagogical knowledge)-**cPCK**

Learner 4: Yes.

Samantha: It's a plant.

Learner 4: A grass (knowledge of the learners)-**ePCK**

Samantha: Grass? (pedagogical knowledge)-**cPCK**

Learner 4: Yes.

Samantha: OK…grass? sharp. Then? (pedagogical knowledge)-**cPCK**

Learners: Sunlight (knowledge of the learners)-**ePCK**

Samantha: What do you get from sunlight? (pedagogical knowledge)-**cPCK**

Learners: Radiant energy (knowledge of the learners)-**ePCK**

Samantha: Can I still write here? (pedagogical knowledge)-**pPCK**…OK. You get radiant energy right? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Right, then we also have another thing which is? (pedagogical knowledge)-**cPCK**

Learners: Carbon dioxide, and water (knowledge of the learners)-**ePCK**

Samantha: These are all the? (pedagogical knowledge)-**cPCK**

Learners: Requirements (knowledge of the learners)-**ePCK**

Samantha: Requirements for photosynthesis. And there are the? (pedagogical knowledge)-**cPCK**

Learners: By-products, products (knowledge of the learners)-**ePCK**

Samantha: Products, products of photosynthesis. Sugar and oxygen. Hau, Ok solar energy plus carbon dioxide, plus water you get glucose plus oxygen. So, this is a balance equation of photosynthesis (content knowledge)-**pPCK**

Learners: Yes.

Samantha: But I they hardly ask you about than but in case you wanna know how to balance the oxygen. Right, then when we magnify onto the glass we see the plant cell right. Then the plant cell inside the plant cell we have the chloroplast, Ok. The chloroplast which where photosynthesis takes place (content knowledge)-**pPCK**. Inside the chloroplast what do we have? What do we have? (pedagogical knowledge)-**cPCK** Before basivezela *(they show us).*

Samantha and the learners: Grana, stroma and ribosomes, lamella, starch grain, thylakoids, double membrane.. (knowledge of the learners)-**ePCK**

Samantha: Right, OK. So, this is where the light phase takes place angithi. In the grana. That is where the chlorophyll is found for absorbing light. NADPH ka learner 11 nayi laphaya ne ATP. Then, there's water also which will be broken down and photolysis. Then oxygen will be released as a by-product of photosynthesis (content knowledge)-**pPCK**. So, oxygen is released in the light phase right? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: Then the stroma that is where the dark phase takes place. Where we will have NADPH plus ATP as a product you get carbohydrate (content knowledge)-**ePCK**. Then the carbon dioxide is the requirement of dark phase. The requirements are sunlight, carbon dioxide, water. Products? Sugar, which is glucose. And? Oxygen. Will be released after photosynthesis has taken place. Then the oxygen is released in the light phase, the sugar is released in the dark phase. Right (content knowledge)-**pPCK**. Activity. Um, I'm giving you twelve minutes. Futhi i12 minutes iningi yaz *(12 minutes is a lot)*. Six minutes. Two minutes left. Right, singamakha *(can we mark)*? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Samantha: OK. Um learner 15 what is phase 1? (pedagogical knowledge)-**pPCK** What is light phase 1? Oh! Phase 1 sorry (pedagogical knowledge)-**pPCK** OK. Light phase. What is phase 2? (pedagogical knowledge)-**cPCK**

Learner 15: Dark phase (knowledge of the learners)-**ePCK**

Samantha: Dark phase. Phase 1 it is light phase; phase 2 it's dark phase right. Um let's see, what are the two raw materials? Or what is the first one? What is A? (pedagogical knowledge)-**cPCK**

Learners: It's a sun (knowledge of the learners)-**ePCK**

Samantha: Yes sunlight or radiant energy. Learner 4 what is B? (pedagogical knowledge)-**pPCK**

Learner 4: Water.

Samantha: Water, then the by-product C? learner 16 what is C? (pedagogical knowledge)-**pPCK**

Learner 16: Oxygen (knowledge of the learners)-**ePCK**

Samantha: Oxygen (pedagogical knowledge)-**pPCK**, which substance is labelled as D is essential for photosynthesis? Oh OK. Sorry, so this, let me start afresh. OK this is the light phase; this is dark phase. And then A we said its sunlight, or radiant energy. Right. Then B is water. Then C is oxygen. Right, um learner 6, what is D? (pedagogical knowledge)-**pPCK**

Learner 6: Carbon dioxide (knowledge of the learners)-**ePCK**

Samantha: Carbon dioxide, and then what is E learner 7? (pedagogical knowledge)-**pPCK**

Learner 7: It is…*inaudible*…

Samantha: Huh?

Learner 7: Glucose (knowledge of the learners)-**ePCK**

Samantha: Glucose, so the product E is yes glucose. And then in what form is product E stored in plants? Product E is glucose. How is it stored in plants? Hau? It was mentioned earlier. Learner 18? (pedagogical knowledge)-**pPCK**

Learner 18: Starch (knowledge of the learners)-**ePCK**

Samantha: Starch. Stored as starch (pedagogical knowledge)-**pPCK** Then the last question, describe the role of raw material labelled A. Raw material labelled A is? (pedagogical knowledge)-**cPCK**

Learners: Sunlight (knowledge of the learners)-**ePCK**

Samantha: Sunlight right, so the sunlight provides us with what?

Learners: Radiant energy (knowledge of the learners)-**ePCK**

Samantha: And then what does that radiant energy do? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Samantha: Yes learner 11.

Learner 11: It helps with phosphorisation (knowledge of the learners)-**ePCK**.

Samantha: It helps with photolysis. Yes it helps with photolysis. So, it is there to split the water to hydrogen and oxygen which is photolysis (content knowledge)-**pPCK**. So, this sunlight energy is absorbed by the chlorophyll that is found in which structure in the chloroplast? (pedagogical knowledge)-**cPCK** Chlorophyll is found in which structure of the chloroplast.?

Learners: Lamella (knowledge of the learners)-**ePCK**

Samantha: Lamella and grana yes. Then what does it do? It splits the water molecule into hydrogen and oxygen. So, if you know that the sun's energy is um absorbed by chlorophyll for photolysis you are also correct. Which is the splitting of water to form hydrogen and oxygen (pedagogical knowledge)-**ePCK**. Right, ngicela nikhipheni amaphone *(please take out your phones).*

APPENDIX 11: Lesson Observational Transcript from school 2 for lesson 2.

Researcher: Uh okay. Sanibonani *(good day),* sanibonani.

Learners: Yebo.

Researcher: Alright. So, it's an experiment but we won't be doing the actual experiment. We will be doing the smartboard. So, starch test. Right. Ok, so the objectives of this lesson is to make sure that uh you're able to list and describe uh the materials or the apparatus neh that are needed for this specific experiment. Remember to 'test for starch' there's different types neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: Then you also need to know uh the significance of each step. Why are we doing this? Why are we doing that neh. Another thing uh you need to know uh relate the presence of starch in the leaf to the production of glucose during photosynthesis. You should know if starch is present what does it tell you. If it's absent what does it tell you neh. Yah and yah. You should also be able to observe the changes in the leaf. Because the changes in the leaf they also tell you something neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: OK. So, these are the apparatus for starch test neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: So, what is this?(pedagogical knowledge)-**cPCK**

Learners: Iodine solution. (learning context)-**ePCK**

Researcher: How do you write iodine solution? (pedagogical knowledge)-**cPCK**

Learners: I…

Researcher: OK. Nizong'tshela phela *(you will tell me)*. Mina angazi lutho neh *(I don't know anything)*. So, you're saying this is? (pedagogical knowledge)-**cPCK**

Learners: Iodine solution. (learning context)-**ePCK**

Researcher: Iodine solution neh. (pedagogical knowledge)-**pPCK**

Researcher and the learners: I O D I N E

Researcher: Neh.

Learners: Yes.

Researcher: Solution?

Learners: S O L U T I O N. (learning context)-**ePCK**

Researcher: Iodine solution(pedagogical knowledge)-**pPCK** neh. What's what's the original colour for iodine solution? Is it purple? (pedagogical knowledge)-**cPCK**

Learners: No. Brown. (learning context)-**ePCK**

Researcher: It's pink? (pedagogical knowledge)-**cPCK**

Learners: Brown. (learning context)-**ePCK**

Researcher: Huh?

Learners: Brown. (learning context)-**ePCK**

Researcher: Brown neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: So, sometimes they will tell you that its reddish brown neh. OK. Right. Now, what is this? Yini le? What is this? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: OK OK. If you don't know what it is are you able to describe how do you use it? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Alright keh how do you use it? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: You put inside the iodine solution and then you squeeze it neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: So, this is called a dropper neh. (content knowledge)-**pPCK**

Learners: Oh.

Researcher: It's a dropper(content knowledge)-**pPCK**. Now you know neh.

Learners: Yes.

Researcher: Yah so you know this is how you use it. Alright. Uh and then what is this? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: OK OK if you don't know what it is maybe you can describe how do you use it neh. (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: OK. How do you use it? What do you use it for? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: This is for having fire neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: So, you know the name, but you know what you use if for.

Learners: Yes.

Researcher: OK. So, this is a Bunsen, Bunsen Burner. So, it's a Bunsen Burner neh. So, this one it's, this is the one that you. You use gas for this neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: Yah you connect this one to gas. If you don't have this one. You use eh the manual one. So, it's like the manual one(content knowledge)-**pPCK**. It will be the same thing neh but inside eh you see here? It will be like a cup neh and then there will have to be a string inside neh. Then you can use what? A sanitizer or? (pedagogical knowledge)-**cPCK**

Learners: A spirit. (learning context)-**ePCK**

Researcher: A spirit and you use a match to start fire(content knowledge)-**pPCK**. OK. Right. Then what is this? (pedagogical knowledge)-**cPCK**

Learners: Glass beaker. (learning context)-**ePCK**

Researcher: It's a glass beaker neh. Yah there's also a plastic one(content knowledge)-**pPCK**. Right.

Learners: Yes.

Researcher: OK. This is a beaker(learning context)-**ePCK**. OK. Girls, ladies yini le? Uh girls they don't know this. Girls you don't know what this is? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: Batshele *(tell them),* it's a what? (pedagogical knowledge)-**cPCK**

Learner 1: It's a tweezer. What do you use the tweezer for in your everyday life? Girls what do you use the tweezer for? (pedagogical knowledge)-**cPCK**

Learners: Ama eyelash.

Researcher: You use it for? (pedagogical knowledge)-**cPCK** Yah yah some some some girls they use it for for for tweezing their eyebrows yah. Abanye ke *(some)* they use it for vele to to insert ama eyelash. Some of them they use it to trim their eyebrows. But but keh lana cause we don't use ama eyelash in this investigation. We don't use eyelashes. So, we use it to hold something neh. So, we using the tweezer hold the leaf neh. So, what is this? (pedagogical knowledge)-**cPCK**

Learners: Test tube. (learning context)-**ePCK**

Researcher: This one. This one. This is a test…(pedagogical knowledge)-**pPCK**

Learners: Tube. (learning context)-**ePCK**

Researcher: Tube neh. (pedagogical knowledge)-**pPCK** Yes this is a test tube(content knowledge)-**pPCK**. Ok. And then what about this? If if you don't know the name think about what can you use it for? (pedagogical knowledge)-**cPCK**

Learners: To hold. (learning context)-**ePCK**

Researcher: To hold what? (pedagogical knowledge)-**cPCK**

Learners: A leaf. (learning context)-**ePCK**

Researcher: To hold what? (pedagogical knowledge)-**cPCK**

Learners: The leaf.

Researcher: Look at this. Look at this. What this, look at this space here. Its big enough to hold what? (pedagogical knowledge)-**cPCK**

Learners: The test tube. (learning context)-**ePCK**

Researcher: The test tube neh. Yah so this one is big enough to hold a test tube. So, we call this a test tube holder neh. If you don't call it a test tube holder there's another word neh. It's a thong. (content knowledge)-**pPCK**

Learners: A thong. (learning context)-**ePCK**

Researcher: Neh.

Learners: Yes.

Researcher: It's a thong.

Learners: It's a thong? (learning context)-**ePCK**

Researcher: Yah like. Right. Cause there's another one that that looks like a scissor. Yah a thong that looks like as scissor. But but it holds the what? The test tub e. It does does not cut the test tube neh. And then what is this here? (pedagogical knowledge)-**cPCK**

Learners: Ethanol. (learning context)-**ePCK**

Researcher: Ethanol(pedagogical knowledge)-**pPCK**. What's the everyday word for ethanol? (pedagogical knowledge)-**cPCK**

Learners: Alcohol. (learning context)-**ePCK**

Researcher: Alcohol neh. (pedagogical knowledge)-**pPCK** So, this is another word for ethanol will be alcohol neh(content knowledge)-**pPCK**. Yes. So, are are you following? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Let me move on. Now there's two things here neh. Ngifuna le ephezulu *(I want the one on top)*. What is this one? (pedagogical knowledge)-**cPCK**

Learners: Sieve. (learning context)-**ePCK**

Researcher: If you don't call it that what else can you call it? (pedagogical knowledge)-**cPCK**

Learner 1: Stand. (learning context)-**ePCK**

Researcher: Hha. The stand is the one that…this here with the three legs. This is the tripod stand neh. Yes this one. The the the three legs. You see this here? It's a tripod stand neh. Right. But this one, this one here it's a what? (pedagogical knowledge)-**cPCK**

Learner 2: Sieve. (learning context)-**ePCK**

Researcher: It's a what? (pedagogical knowledge)-**cPCK**

Learner 2: Sieve. **(learning context)-ePCK**

Researcher: It's a…in Zulu you call it what? (pedagogical knowledge)-**cPCK**

Learners: Is'sefo *(sieve)*

Researcher: Is'sefo *(sieve)* neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: But also, there's another word that they like to use. A gauze neh. (content knowledge)-**pPCK**

Learners: A what?

Researcher: Yah, yah a gauze neh. And then this one? (pedagogical knowledge)-**cPCK**

Learners: Leaf.

Researcher: Leaf neh. So, for this uh practical you can use any leaf as long as it's a what? It's a green leaf. So, you need a green leaf(content knowledge)-**pPCK**. Then what is this? (pedagogical knowledge)-**cPCK**

Learners: It's water. (learning context)-**ePCK**

Researcher: Water neh.

Learners: H_2O (learning context)-**ePCK**

Researcher: H?

Learners: O_2(learning context)-**ePCK**

Researcher: Where do I put the 2? Here? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: Here? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: Should it be big? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: OK. It's supposed to be.

Learners: Small.

Researcher: Alright. So, its H, H_2O neh (content knowledge)-**pPCK**. Now this one. What about this one? Let me ask you this, when you cook food neh what do you do afterwards? (pedagogical knowledge)-**cPCK**

Learners: You dish up.

Researcher: You dish up neh.

Learners: Yes.

Researcher: So, this is the dish neh. It's a petri dish. Yes, it's a petri dish (content knowledge)-**pPCK**. Hhayi learner 2. Petri dish neh. OK. Who's learner 2? OK um uh guys. OK. Right. So, um thank you. When you go to a lab you need to dress a certain way neh.

Learners: Yes.

Researcher: If you don't dress a certain way they kick you out. They used to kick us out in labs in varsity.

Learners: Huh.

Researcher: Yes, ask Ma'am. If you're wearing short skirts they will send you back. You can't enter. You're wearing open shoes; they send you back. If you don't have the lab coat they send you back neh. So, these are the important things that you should have before you enter the lab especially if you're there to do an experiment. Now why? First of all, you will need gloves cause when you're doing experiments sometimes you work with substances that are toxic neh. Sometimes you will be working maybe using acids neh. So, if that acid is going to fall eh in your hands, it has to go through the gloves before it gets to your skin and that buys you time to remove the what? The gloves neh. Then you will need, what are these? (pedagogical knowledge)-**cPCK**

Learners: Googles. (learning context)-**ePCK**

Researcher: Googles neh(pedagogical knowledge)-**pPCK**. Yes safety googles neh. Obviously, you use to protect your arms neh. (content knowledge)-**pPCK**

Learners: Your eyes. (learning context)-**ePCK**

Researcher: Your eyes right. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: So, you use this for protection neh(content knowledge)-**pPCK**. For what? (pedagogical knowledge)-**cPCK**

Learners: For eyes. (learning context)-**ePCK**

Researcher: For eyes neh. (pedagogical knowledge)-**pPCK** Yes. And then you will need what? (pedagogical knowledge)-**cPCK**

Learners: Coat.

Researcher: A lab coat(pedagogical knowledge)-**pPCK** neh. Yes, a lab coat. Then your shoes. You see, your shoes they have to be closed. You can't wear a heel, ngeke ugqoke amaqhops *(you cannot wear heels)* and you're going to the lab. You can't neh. So, you need to wear flat shoes that are what? That are closing your toes neh. Then you also need to wear long pants or long skirt neh. Yah see your glove. So, it's like you're covering your body in a way neh. Yes, the lab coat, the googles. Then there's another one that's missing here, a mask. Cause some of the material that you are using the smell is too strong neh. So, you will need that mask(content knowledge)-**pPCK**. OK. Right, now you're going to watch the animation. There's no voice over. I'll be the voiceover for you neh. OK. Right. This is? (pedagogical knowledge)-**cPCK** OK. Now, this is how you set up your experiment. Remember first you have that attire neh. You have your gloves, you have your safety googles, you have your mask, you have your lab coat, your shoes are covering your toes and everything neh. So, the first thing you will need this tripod stand neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: Why do you need the tripod stand? Cause you have to boil the water and what are you going to use to boil the water? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: You're using what to boil the water? The beaker neh. You need to pour the water in the beaker neh. Then you'll need the tripod stand neh. Why? Cause here underneath you're going to have what? The Bunsen Burner that will give you what? (pedagogical knowledge)-**cPCK** Fire neh. Cause you can't boil the water without the fire. OK. So, you when you boil the water because it's not a lot of water. It's not gonna boil for a a long time. You only gonna boil it for like five minutes max neh. OK. Then once the water starts boiling you're going to take your tweez your thingy your leaf neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: You take the leaf you place it inside where? Inside the boiling water neh. OK. So, you have your tripod stand, you have your Bunsen Burner, you have your water, you have your beaker. You will take your leaf; you will place it inside the water. You allow the leaf to boil neh. You see! The leaf is boiling(content knowledge)-**pPCK**. Why are we boiling the leaf? (pedagogical knowledge)-**cPCK**

Learners: To destarch. (learning context)-**ePCK**

Researcher: Why are we boiling the leaf? (pedagogical knowledge)-**cPCK**

Learners: To destarch. (learning context)-**ePCK**

Researcher: No. Think again. Why are you boiling it? (pedagogical knowledge)-**cPCK**

Learner 3: To break the cell wall. (learning context)-**ePCK**

Researcher: To break the cell wall, to stop also the activities that are taking place inside the leaf. Because remember the photosynthesis is not the only thing that takes place inside the leaf neh. There's also other processes that are taking place like you're your protein synthesis in the ribosome neh. So, when you boil the leaf, you you are stopping all the cells activities neh. OK, let's continue. Now once you're done boiling the leaf you're going to remove it(content knowledge)-**pPCK**. You place where? In the? (pedagogical knowledge)-**cPCK**

Learners: Petri dish.

Researcher: Petri dish(pedagogical knowledge)-**pPCK**. Remember the, what's this? (pedagogical knowledge)-**cPCK** This one.

Learner 3: Test tube. (learning context)-**ePCK**

Researcher: Test tube. Thank you (pedagogical knowledge)-**pPCK**. Yes, so you are you will place it here in the petri dish then you will take your test tube neh. When you take your test tube you're going to pour in that leaf neh. (content knowledge)-**pPCK** Then in the leaf you will pour what? (pedagogical knowledge)-**cPCK** The alcohol neh. Yes. So, alcohol AKA alcohol, ethanol neh. Then you will take the same test tube that has the leaf with the alcohol, you place it inside the water bath neh(content knowledge)-**pPCK**. Now can you tell me. Why are we uh boiling this alcohol with the leaf inside the other beaker with the water? Why don't you just place alcohol in this beaker and then the leaf and let it boil? (pedagogical knowledge)-**cPCK**

Learner 4: Because alcohol is flammable (learning context)-**ePCK**

Researcher: Yes because alcohol is flammable. So, when you boil it inside this water, you are now using water as a water bath to prevent any flames neh. Cause we know flames they can start fire neh. It can be a small beaker, but it can burn the entire classroom. Or your legs we don't know. OK(content knowledge)-**pPCK**. Then you let it boil. So, now another thing why are we boiling this leaf in the alcohol? Why are we boiling the leaf inside the alcohol? Think about it. Why? What is that substance that absorbs the sunlight? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll. (learning context)-**ePCK**

Researcher: So, when you boil it you are removing all the chlorophyll neh. Yes. So, when you boil you're removing the chlorophyll neh. Yes. So, when you…also you don't boil it for a long time, you boil it for like few minutes neh. (content knowledge)-**pPCK** And as you boil it you will see the leaf will start changing colour. It will move from being green and become what? (pedagogical knowledge)-**cPCK**

Learners: Colourless.

Researcher: Colourless you see. It starts changing colour. And then when you see that it's it's now changing colour it's no longer green. You now remove the leaf neh. But when you remove the leaf, uh you need to understand that it will be stiff. OK. Yes. So, you will remove the leaf, then also again you will place it inside the water to make it soft neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: OK. Then when you are done, you see you're now going to take your? (pedagogical knowledge)-**cPCK**

Learners: Iodine solution. (learning context)-**ePCK**

Researcher: Iodine solution. What do you use to take out the iodine solution? (pedagogical knowledge)-**cPCK**

Learners: A dropper.

Researcher: A dropper(pedagogical knowledge)-**pPCK**. So, you will take that dropper, you will take out the iodine solution then you will drop, just few drops. You don't need a lot of drops neh. So, you just drop few drops, and you are now going to observe what happens. Hhaa huh. OK. Right. So, you will observe what happens neh. Now what you are going to observe is you see there's there's two things neh. The'll be a leaf, The'll be the iodine solution. You observe what happen to the iodine solution not the leaf neh. So, you observe what happens to the iodine solution. Cause without the iodine solution there won't be anything to observe neh. So, when you observe you look at the colour change(content knowledge)-**pPCK**. Are are you going to have any colour changes or what? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Yes. Haibo! OK. So, if the leaf is um the iodine solution in the leaf, if its reddish brown what does it tell you? (pedagogical knowledge)-**cPCK**

Learners: There is no starch. (learning context)-**ePCK**

Researcher: Let me go back here. Let me go back here. OK. Now watch again. (pedagogical knowledge)-**cPCK** You see. If you drop the iodine solution and it does not change colour it remains reddish brown that tell you that there is no starch. However, if you drop the iodine solution and then you can see this colour change. You see its now becoming blue-black. (content knowledge)-**pPCK** That's an indication that there is what? (pedagogical knowledge)-**cPCK**

Learners: Starch. (learning context)-**ePCK**

Researcher: There is starch neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: OK. Then now eh let's move on. Again, this is the same thing neh. This is the diagram(SAMR). What's the first thing that you are going to do when you test for starch? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: You you fill what? (pedagogical knowledge)-**cPCK**

Learners: Your glass beaker. (learning context)-**ePCK**

Researcher: You need to fill water in the glass beaker neh. You need to water in the glass beaker. (content knowledge)-**pPCK** What is this water for? (pedagogical knowledge)-**cPCK**

Learners: Boiling the leaf. (learning context)-**ePCK**

Researcher: To boil what? (pedagogical knowledge)-**cPCK**

Learners: The leaf. (learning context)-**ePCK**

Researcher: To boil the leaf neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: Because eh if it didn't come out in your SBA. Your SBA was photosynthesis neh.

Learners: Yes.

Researcher: If you didn't see it in your June exam, you are more likely to see it in your final exam. In your final exam they can give you eh eh an investigation about photosynthesis then they say describe four steps that are taken during this uh process. You need to know the first thing you do what? You boil the water for about four to five minutes neh. Then you boil water to do what? Why are you boiling the water? Why are you boiling, sorry why are you boiling the green leaf to water? (pedagogical knowledge)-**cPCK**

Learners: To stop cell (learning context)-**ePCK**

Researcher: To stop what? You boil the leaf to stop all the activities in the cell neh. Yah. Uh what's going on here? OK. So, you boil the leaf to do what? To stop? (pedagogical knowledge)-**cPCK**

Learners: The activities. (learning context)-**ePCK**

Researcher: The cell's activities neh. Yah. Activities(pedagogical knowledge)-**pPCK**, alright. And then when you're done boiling the leaf what are you going to do? You will take it out and then you will do what? (pedagogical knowledge)-**cPCK**

Learners: Place in the test tube. (learning context)-**ePCK**

Researcher: That when you're done what are you going to do next? (pedagogical knowledge)-**cPCK**

Learners: Boil it in the alcohol. (learning context)-**ePCK**

Researcher: You fill the test tube with? (pedagogical knowledge)-**cPCK**

Researcher and the learners: Alcohol.

Researcher: Then what are you going to do next? (pedagogical knowledge)-**cPCK**

Learners: Place it in the test tube. (learning context)-**ePCK**

Researcher: You place the leaf back to the test tube. (pedagogical knowledge)-**pPCK** Then when you're done, what are you going to do next? (pedagogical knowledge)-**cPCK**

Learners: You place it inside the water bath. (learning context)-**ePCK**

Researcher: You place it inside the water bath(pedagogical knowledge)-**pPCK**. Can you see, this is a water bath. Why do we need the water bath? (pedagogical knowledge)-**cPCK**

Learner 5: To prevent fires. (learning context)-**ePCK**

Researcher: To prevent what? (pedagogical knowledge)-**cPCK**

Learners: Flames. (learning context)-**ePCK**

Researcher: Neh. To prevent hazards such as flames neh(pedagogical knowledge)-**pPCK**. Yah, to prevent fire OK. OK. And then when you're done boiling it in that uh ethanol, what are you going to do next? (pedagogical knowledge)-**cPCK**

Learners: You take it out and place it in cold water. (learning context)-**ePCK**

Researcher: You take it out and place it in cold water. (pedagogical knowledge)-**pPCK** Why do you place it in cold water? (pedagogical knowledge)-**cPCK**

Learners: Because it must be soft. (learning context)-**ePCK**

Researcher: So, to make it soft neh(pedagogical knowledge)-**pPCK**. Yes. To make the leaf, to make the leaf soft neh. Alright. And then when you are done, what are you going to do? (pedagogical knowledge)-**cPCK**

Learners: Place it in the petri dish. (learning context)-**ePCK**

Researcher: You place it in the petri dish(pedagogical knowledge)-**pPCK**. You know that this is the what? Petri dish neh. OK when you're done placing it in the petri dish what's the next thing that you're going to do? (pedagogical knowledge)-**cPCK**

Learners: You take the iodine solution. (learning context)-**ePCK**

Researcher: You take the dropper. OK this is the dropper. Right. What are you going to do with the dropper? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: You drop, you you pour few drops of what? (pedagogical knowledge)-**cPCK**

Learners: Iodine solution. (learning context)-**ePCK**

Researcher: Iodine solution to the leaf. Alright. Then here you have the two leaves neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: What colour is this? (pedagogical knowledge)-**cPCK**

Learners: Brown. (learning context)-**ePCK**

Researcher: Reddish brown neh. (pedagogical knowledge)-**pPCK** Yes. So, its reddish brown and then what colour is this? (pedagogical knowledge)-**cPCK**

Learners: Blue-black. (learning context)-**ePCK**

Researcher: This is now blue…

Learners: Black. (learning context)-**ePCK**

Researcher: Black. (pedagogical knowledge)-**pPCK** What does blue-black indicate? (pedagogical knowledge)-**cPCK**

Learners: Starch is present. (learning context)-**ePCK**

Researcher: Starch is present neh. (pedagogical knowledge)-**pPCK** Now there's two things that you need to uh know. They can ask you about uh results then they can ask you about conclusion neh.

Learners: Yes.

Researcher: In relation to this and you should know when they say results they want you to speak about what you can see. The results it's what you can see meaning that you did this and this and this and now here are the results neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: It's what you can see. So, the results, if the question is asking you about the results, you don't spak about starch is present starch is absent. You speak about the colour change neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: You will indicate that um there was a colour change from reddish brown to blue-black. Now if they ask you about conclusion, now that is where you can say there is no starch. Meaning what? Photosynthesis did not take place or starch is present an indication that photosynthesis has taken place. Is this experiment making sense? Is there anything that you want us to go back to? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: OK. Right. Now these activities you need to do it ASAP cause there's another one that's coming after this one. Yes, it's OK I'm with you. We are in this together. Or maybe we don't even need to write. (assessment knowledge)-**ePCK**

Learners: Yes.

Researcher: Let's do it here in the chalkboard. Now, why was the leaf initially put in the beaker of boiling water? Why? (pedagogical knowledge)-**cPCK**

Learners: To stop all the cell activities. (learning context)-**ePCK**

Researcher: To what? (pedagogical knowledge)-**cPCK**

Learners: To stop all the cell activities. (learning context)-**ePCK**

Researcher: Uh we said we are doing activity as a class, but people are quiet. To do what? (pedagogical knowledge)-**cPCK**

Learners: To stop the cell activities. (learning context)-**ePCK**

Researcher: To stop the cell activities(pedagogical knowledge)-**pPCK** neh. So, we know that in the leaf there is what? There is cell activities taking place neh (content knowledge)-**pPCK**.

So, if you boil it what do you do to these activities? You stop them neh. OK. Now why do we boil the leaf in the alcohol? (pedagogical knowledge)-**cPCK**

Learners: To remove chlorophyll. (learning context)-**ePCK**

Researcher: To remove what? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll. (learning context)-**ePCK**

Researcher: To remove chlorophyll(pedagogical knowledge)-**pPCK**. OK. So, now they say why do why was why was the test tube with boiling water placed inside a glass beaker? (pedagogical knowledge)-**cPCK**

Learners: To prevent fire. (learning context)-**ePCK**

Researcher: To prevent what? (pedagogical knowledge)-**cPCK**

Learner 4: Fire. (learning context)-**ePCK**

Researcher: Hazards neh. Like what? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: Yah because we know that the alcohol is what? (pedagogical knowledge)-**cPCK**

Learners: Flammable. (learning context)-**ePCK**

Researcher: Alcohol is flammable neh(pedagogical knowledge)-**pPCK**. So, we need to make sure that we don't catch any flames. OK. Now which colour change is observed in the leaf? When there is a starch? (pedagogical knowledge)-**cPCK**

Learners: It will turn blue-black. (learning context)-**ePCK**

Researcher: It will turn blue-black(pedagogical knowledge)-**pPCK**. So, the colour change will be from what colour to what colour? (pedagogical knowledge)-**cPCK**

Learners: *Mumbling.*

Researcher: It will be from? (pedagogical knowledge)-**cPCK**

Learner 5: Reddish brown. (learning context)-**ePCK**

Researcher: Reddish brown. (pedagogical knowledge)-**pPCK** So, when you speak about the colour guys, eh, you don't speak in relation to the leaf. You're looking at the iodine solution neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: When you're asked about the colour change you're looking at the iodine solution not the leaf neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: So, you know that it will move from reddish brown to blue.

Learners: Blue-black. (learning context)-**ePCK**

Researcher: To blue-black neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: OK. So, now here results again. What did I say about results? You speak about what? (pedagogical knowledge)-**cPCK**

Learners: The colour. (learning context)-**ePCK**

Researcher: You speak you speak about what you see. The colour change neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: From reddish brown to(pedagogical knowledge)-**pPCK**.

Learners: Blue-black. (learning context)-**ePCK**

Researcher: Now what did I say about conclusion? (pedagogical knowledge)-**cPCK**

Learners: Starch is present. (learning context)-**ePCK**

Researcher: Starch is present neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: Now chemical equation. I'm not writing the chemical equation. You're going to tell me what to write. What do I ? How do you write the chemical equation for photosynthesis? How do you write it? (pedagogical knowledge)-**cPCK**

Learners: CO_2 (learning context)-**ePCK**

Researcher: CO_2(pedagogical knowledge)-**pPCK**

Learners: Plus, H_2O (learning context)-**ePCK**

Researcher: Plus? (pedagogical knowledge)-**cPCK**

Learners: H_2O. (learning context)-**ePCK**

Researcher: H_2O plus? (pedagogical knowledge)-**cPCK**

Learners: CO_2, ATP(learning context)-**ePCK**

Researcher: Hau What what else? What do I do guys? You are saying what? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible*…Sunlight.

Researcher: So, you're saying that I need to add what? (pedagogical knowledge)-**cPCK**

Learners: Arrow.

Researcher: An arrow. OK and then? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: Here I write? (pedagogical knowledge)-**cPCK**

Learners: Radiant energy. (learning context)-**ePCK**

Researcher: Radiant energy. (pedagogical knowledge)-**pPCK**

Learners: Enzymes. (learning context)-**ePCK**

Researcher: Where do I put enzyme? (pedagogical knowledge)-**cPCK**

Learners: Ngaphansi. *(at the bottom)*

Researcher: Then after the arrow? (pedagogical knowledge)-**cPCK**

Learners: $C_6H_{12}O_6$. (learning context)-**ePCK**

Researcher: C?

Learners: C_6. (learning context)-**ePCK**

Researcher: 6.

Learners: H_{12}. (learning context)-**ePCK**

Researcher: H_{12}.

Learners: O_6. (learning context)-**ePCK**

Researcher: O_6. (pedagogical knowledge)-**pPCK**

Learners: Plus O_2. (learning context)-**ePCK**

Researcher: Plus?

Learners: O_2. (learning context)-**ePCK**

Researcher: So, the word. What does CO_2 stand for? (pedagogical knowledge)-**cPCK**

Learners: Carbon dioxide. (learning context)-**ePCK**

Researcher: What about this H_2O? (pedagogical knowledge)-**cPCK**

Learners: Water. (learning context)-**ePCK**

Researcher: What about the $C_6H_{12}O_6$? (pedagogical knowledge)-**cPCK**

Learners: Glucose. (learning context)-**ePCK**

Researcher: What about the O_2? (pedagogical knowledge)-**cPCK**

Learners: Oxygen. (learning context)-**ePCK**

Researcher: Neh. OK. Now eh Ma'am, this is the memo. You will get the everything from Ma'am neh.

Learners: Yes.

Learners: *Mumbling.*

Learner 6: Nkadime pencil.

Learners: *Mumbling.*

Researcher: Eh OK guys neh. So, you need to see if whether the words that we were speaking about you know them neh.

Learners: Yes.

Researcher: So, now there will be one word. You have 30 seconds to tell me anything that you can tells about that word neh.(assessment knowledge)-**ePCK**

Learners: Yes.

Researcher: Angazi. Are you ready? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: No. You're not ready. Basakhuluma ngama bear.

Learners: *Mumbling.*

Researcher: OK. Uh your time starts now. What can you tell me about the word starch? Nothing? You don't know anything? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: Glucose is stored in the form of starch. OK. What else? That's all? That's all you know about starch. Nothing else? (pedagogical knowledge)-**cPCK**

Learner 6: The plant turns blue-black when it has starch. (learning context)-**ePCK**

Researcher: The the the leaf will will turn blue-black when the starch is present. (pedagogical knowledge)-**pPCK** OK. Time is up neh. OK.

Learner 1: Uyasi timer?

Researcher: Yah ngiyani timer to see how fast you are. You don't. you must know your words neh.

Learners: Yes.

Researcher: You cannot be a life sciences learner and not know your words. You can't. OK. Next word. Are you ready? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: OK. Right. Tell me.

Learners: Used to test for starch. (learning context)-**ePCK**

Researcher: It is used to test for starch(pedagogical knowledge)-**pPCK**. What else? (pedagogical knowledge)-**cPCK**

Learner 5: It is reddish brown. (learning context)-**ePCK**

Researcher: It is reddish brown neh. (pedagogical knowledge)-**pPCK** What else? (pedagogical knowledge)-**cPCK**

Learner 6: It turns blue-black when in the present of starch. (learning context)-**ePCK**

Researcher: It turns blue-black in the presence of starch(pedagogical knowledge)-**pPCK**. What else can you say? What else can you say? (pedagogical knowledge)-**cPCK**

Learners: It remains reddish brown when there is no starch. (learning context)-**ePCK**

Researcher: It remains reddish brown when there is no starch neh(pedagogical knowledge)-**pPCK** …*inaudible*…

Learners: It is the main product of photosynthesis. (learning context)-**ePCK**

Researcher: Main product of? (pedagogical knowledge)-**cPCK**

Learners: Photosynthesis. (learning context)-**ePCK**

Researcher: OK. What else? (pedagogical knowledge)-**cPCK**

Learners: It is stored as starch. (learning context)-**ePCK**

Researcher: Glucose is stored as what in the plant? (pedagogical knowledge)-**cPCK**

Learners: A starch. (learning context)-**ePCK**

Researcher: A starch neh(pedagogical knowledge)-**pPCK**. What else can you tell me about glucose? Come on guys, is this the only thing you know about the glucose? (pedagogical knowledge)-**cPCK**

Learner 7: Kuma Animals…

Researcher: Is this the only thing you know about the glucose? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: Awa, awa guys listen neh. Let's listen.

Learner 8: Asiqalele phantsi.*(let's start all over)*

Researcher: A angeke siqalele phantsi *(we won't start all over).* You need to you guys only told me two things. Hah you guys. Heh eh listen. You said to me neh. Eh, glucose it's the main product of photosynthesis.

Learners: Yes.

Researcher: Glucose is stored as starch. Is that the only thing you know? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: There's other things you can say. Like the chemical formula for glucose is $C_6H_{12}O_6$. Hhayiii. You must also be fast neh. OK. It's fine. Let's see if it's the time or its you neh. One to five.

Learners: It's a green pigment. (learning context)-**ePCK**

Researcher: It's a green pigment. (pedagogical knowledge)-**pPCK** Where do you it? (pedagogical knowledge)-**cPCK**

Learners: In the chloroplast, in the grana. (learning context)-**ePCK**

Researcher: In the plant? In the what? (pedagogical knowledge)-**cPCK**

Learners 8: In the organelle chloroplast. (learning context)-**ePCK**

Researcher: In the leaf, where? (pedagogical knowledge)-**cPCK**

Learners: Organelle chloroplast. (learning context)-**ePCK**

Researcher: In the what? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast. (learning context)-**ePCK**

Researcher: Chloroplast. (pedagogical knowledge)-**pPCK** OK. Yes what does it do? (pedagogical knowledge)-**cPCK**

Learner 6: It's used to trap sunlight. (learning context)-**ePCK**

Researcher: It what? (pedagogical knowledge)-**cPCK**

Learners: Absorbs sunlight. (learning context)-**ePCK**

Researcher: Absorbs sunlight neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: OK. Why? Uh time time time. You must be quick neh.

Learners: Yes.

Researcher: And if you see a word, you can say a lot of things with one word. You know that neh.

Learners: Yes.

Researcher: Next.

Learners: *Inaudible.*

Researcher: It is what? (pedagogical knowledge)-**cPCK**

Learner 8: It is released by plants. (learning context)-**ePCK**

Researcher: Released by plants. (pedagogical knowledge)-**pPCK** Yes.

Learner 8: It is used for cellular respiration. (learning context)-**ePCK**

Researcher: By-product, yes.

Learners: *Inaudible.*

Researcher: Huh, this row this row

Learner 9: It is used for cellular respiration. (learning context)-**ePCK**

Researcher: It is released in the light phase.

Learner 9: Used for cellular respiration. (learning context)-**ePCK**

Researcher: For cellular respiration neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: Yes. Anything else you want to add? 3, 2, 1

Learner 8: Humans inhale it. (learning context)-**ePCK**

Researcher: Humans inhale it neh(pedagogical knowledge)-**pPCK**. OK. This row, ai ngeke vukani. OK. Phosphorylation.

Learners: *Inaudible.*

Researcher: Phosphorylation. (learning context)-**ePCK**

Learner 10: Formation of ATP. (learning context)-**ePCK**

Researcher: It's a formation of ATP. (pedagogical knowledge)-**pPCK** Yes, what else can you say besides saying formation of ATP?

Learners: *Inaudible.*

Researcher: Chemical formula is? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: You're forming ATP. You need what? ADP plus? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: Plus, P neh.

Learners: Yes.

Researcher: OK. Time time time time neh. OK, next.

Learners: Chloroplast. Organelle. (learning context)-**ePCK**

Researcher: It's an organelle. (pedagogical knowledge)-**pPCK**

Learners: Where photosynthesis takes place. (learning context)-**ePCK**

Researcher: Where photosynthesis takes place. (pedagogical knowledge)-**pPCK** OK.

Learners: It has grana. (learning context)-**ePCK**

Learner 6: It's only found in plants. (learning context)-**ePCK**

Researcher: It has grana(pedagogical knowledge)-**pPCK**. OK.

Learner 8: It has stroma. (learning context)-**ePCK**

Learner 6: It is only found in plants. (learning context)-**ePCK**

Researcher: It has stroma, it has ribosomes, it has lamella. (content knowledge)-**pPCK**

Researcher: Ribosomes. It has ribosomes, lamella (content knowledge)-**pPCK**

Learner 9: Double membrane. (learning context)-**ePCK**

Researcher: Do you find it in human cells? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: You find it in what? (pedagogical knowledge)-**cPCK**

Learners: Plant cells. (learning context)-**ePCK**

Researcher: Do you know how to draw it? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Come and draw it we shall see.

Learners: Yes. No.

Researcher: Ende ende eh when we get to the last word one of you is gonna come here and draw it. I want to see if…

Learners: Yes.

Researcher: OK.

Learners: *Inaudible.*

Researcher: It's what? (pedagogical knowledge)-**cPCK**

Learners:….in the sun…..(learning context)-**ePCK**

Researcher: Sun traps energy for what? (pedagogical knowledge)-**cPCK**

Learners: For photosynthesis. (learning context)-**ePCK**

Researcher: For photosynthesis. OK. What else can you say about radiant energy? What does it do? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: What does it do? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: What does it do when it enters the plant? (pedagogical knowledge)-**cPCK**

Learners: Used for light phase. (learning context)-**ePCK**

Researcher: It helps with photolysis neh.

Learners: Yes.

Researcher: Woo hai lo uwrong shame.

Learners: Yes.

Researcher: Right.

Learners: The splitting of water into(learning context)-**ePCK** …*inaudible*…

Researcher: The what? (pedagogical knowledge)-**cPCK**

Learners: The splitting of water molecule into hydrogen and oxygen. (learning context)-**ePCK**

Researcher: It's the splitting of water molecules into hydrogen and oxygen. (pedagogical knowledge)-**pPCK** So, you see the difference between photolysis and phosphorylation.

Learners: Yes.

Researcher: Phosphorylation you're forming? (pedagogical knowledge)-**cPCK**

Learners: ATP. (learning context)-**ePCK**

Researcher: Photolysis you're spliting? (pedagogical knowledge)-**cPCK**

Learners: Water molecules. (learning context)-**ePCK**

Researcher: Neh. Alright. So, I think you're fine with this one neh.

Learners: Yes.

Researcher: Carbon dioxide.

Learners: It is used in the dark phase. It is used by plants for photosynthesis. (learning context)-**ePCK**

Researcher: It is used by plants for photosynthesis.

Learners: *Inaudible.*

Researcher: Huh, requirement for dark phase. Huh! Someone said humans inhale it

Learners: Exhale. (learning context)-**ePCK**

Researcher: Exhale neh.

Learners: Yes.

Researcher: Only humans that exhale carbon dioxide? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: Animals neh.

Learners: Yes.

Researcher: Such as? (pedagogical knowledge)-**cPCK**

Learners: Cows. (learning context)-**ePCK**

Researcher: Cow (pedagogical knowledge)-**pPCK**. Yho ai, OK. Right, let's see.

Researcher and the learners: *Inaudible.*

Researcher: When the iodine solution turns blue-black it tells you that the starch is…

Learners: Starch is present. (learning context)-**ePCK**

Researcher: OK. What else? (pedagogical knowledge)-**cPCK**

Learners: Ama hairpiece akhona a blue-black. *(Blue-black hairpieces are available)*

Samantha: Ama hairpiece?

Researcher: OK. If its blue-black it means it changed from what colour? (pedagogical knowledge)-**cPCK**

Learners: Reddish brown. (learning context)-**ePCK**

Researcher: Alright. OK.

Learners: Stroma. (learning context)-**ePCK**

Researcher: It's a what? (pedagogical knowledge)-**cPCK**

Learners: It's a dark phase. (learning context)-**ePCK**

Learner 6: Dark phase. (learning context)-**ePCK**

Researcher: It's not a light phase; it's not a dark phase but it's a what? It's a its something. You're going to write something. The stroma it's a site; it's a site for dark phase. It's a site for? (pedagogical knowledge)-**cPCK**

Researcher and the learners: Dark phase.

Researcher: So, it's a site. Right.

Learners: Yes.

Researcher: Reddish brown let's see.

Learners: *Inaudible.*

Researcher: It's a colour of the iodine solution neh. So, if you see reddish brown in the leaf what does it indicate? (pedagogical knowledge)-**cPCK**

Learners: There's no starch. (learning context)-**ePCK**

Researcher: Starch is? (pedagogical knowledge)-**cPCK**

Learners: Absent.

Researcher: Absent neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: Right. Let's see.

Learners: Stomata. (learning context)-**ePCK**

Researcher: Stomata. (pedagogical knowledge)-**pPCK**

Learners: The opening for gaseous exchange. (learning context)-**ePCK**

Researcher: Stomata is the what?

Learners: Opening for gaseous exchange. (learning context)-**ePCK**

Researcher: Opening of gaseous exchange(pedagogical knowledge)-**pPCK**. Where is this opening? (pedagogical knowledge)-**cPCK**

Learners: In the guard cells, in the leaves. (learning context)-**ePCK**

Researcher: In the leaf neh.

Learners: Yes.

Researcher: Stomata is the opening in the leaf for? What do you find around the stomata? (pedagogical knowledge)-**cPCK**

Learners: Guard cells. (learning context)-**ePCK**

Researcher: Guard cells neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: They are the one responsible for doing what? (pedagogical knowledge)-**cPCK**

Researcher and the learners: For opening and closing the stomata. (learning context)-**ePCK**

Researcher: Which gas comes in? (pedagogical knowledge)-**cPCK**

Learners: Carbon dioxide. (learning context)-**ePCK**

Researcher: Which gas comes out? (pedagogical knowledge)-**cPCK**

Learners: Oxygen.

Researcher: Right.

Learners: It's a site for light phase; it's a site for light phase. (learning context)-**ePCK**

Researcher: It's a site for? (pedagogical knowledge)-**cPCK**

Learners: Light phase. (learning context)-**ePCK**

Researcher: Now you know that the stroma it's a site for.

Learners: Dark phase. (learning context)-ePCK

Researcher: The grana it's a site ? (pedagogical knowledge)-**cPCK**

Learners: Light phase. (learning context)-ePCK

Researcher: What do you find inside the grana? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll. (learning context)-**ePCK**

Researcher: Chloro what does the chlorophyll do? (pedagogical knowledge)-**cPCK**

Learners: Traps sunlight. (learning context)-**ePCK**

Researcher: The sunlight will do what? The sunlight will do what? (pedagogical knowledge)-**cPCK**

Learners: Photolysis. (learning context)-**ePCK**

Researcher: Will do, will go, will split the water molecules into what? (pedagogical knowledge)-**cPCK**

Learners: Hydrogen(learning context)-**ePCK**.

Researcher: Oxygen and? (pedagogical knowledge)-**cPCK**

Learners: Hydrogen. (learning context)-**ePCK**

Researcher: Neh, yah. Now remember you guys you said you said you know how to draw a chloroplast.

Learners: Yes.

Researcher: Who is drawing the chloroplast? (pedagogical knowledge)-**cPCK**

Learners: Learner 11 is drawing. Learner 11.

Researcher: Yah we want to see and then neh the last time I checked it was not learner 11 alone who said yes. I saw everyone who said yes. Who' drawing? Nangu u learner 13. Come.

Learner 6: Awunayo incwadi? Thathi ncwadi kau *(you don't have a book?, take a book bro)*

Learners: Ayayayayayayayayaya!

Samantha: ipencil Ma'am.

Learner 6: ipencil.

Samantha: Ngale phambikwesandla *(next to the hand)*

Researcher: OK. So, draw whatever you want. Guys let's see. This is the chloroplast neh.

Learners: Yes.

Researcher: If you laugh you will come and draw.

Learners: Yho!

Researcher: Mara yiyo guys le *(that's the one)*

Learners: Yes.

Researcher: Or you're saying yes because yes is your favourite word?

Learners: Iyho!

Researcher: This is the one neh.

Learners: Yes.

Researcher: Yah, phela angithi you will never know.

Learners: Iyho!

Researcher: You're going to help neh.

Learners: Yes.

Researcher: So, help her if something is missing you're going to tell her neh.

Learners: Yes.

Learners: Kushoda'istroma *(stroma is missing),* stroma, stroma.

Samantha: Ukhona yeah?

Researcher: What's the stroma?

Learners: Yile…*Mumbling.*

Samantha: Hai kuba ama labels kube asesayidini eliy'one.*(it's the labels, they should be on one side).*

Learners: Iyho!

Researcher: Ubani loyo aze azo drawer eyakhe.*(who's that? They must come and draw theirs)*

Samantha: Yah azo drawer eyakhe (*They must come and draw theirs)*

Researcher: Onenkinga azong' drawela yona *(whoever has a problem they must come draw it).* Eh guys.

Learners: Yes.

Researcher: We not done neh. Eh you see, yes is your favourite word. Eh alright, listen. There's something missing here. What's missing? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: What's missing? (pedagogical knowledge)-**cPCK**

Learner 6: It is the ribosomes. (learning context)-**ePCK**

Researcher: Hha uh. There's something missing. When you draw. Let me tell you something neh. Remember when you draw the teacher neh. When the teacher marks the drawing.

Learners: Heading. Heading. (learning context)-**ePCK**

Researcher: They use these codes neh. CDL neh.

Learners: Yes.

Researcher: So, C, is this the correct drawing? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Okay we said what ? C is what? (pedagogical knowledge)-**cPCK**

Learners: Heading, heading, (learning context)-**ePCK**

Researcher: The D is drawing but we need the heading. What's the heading supposed to be? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast. (learning context)-**ePCK**

Researcher: Chloroplast neh. (pedagogical knowledge)-**pPCK**

Learners: Yes.

Researcher: Yes, so we need heading which is? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast. (learning context)-**ePCK**

Researcher: Do we have correct labels here? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: We have more than three correct labels. What are those labels? (pedagogical knowledge)-**cPCK**

Learners: Yes. Aright wonke.

Researcher: Yah just give me your favourite three.

Learners: Double membrane. (learning context)-**ePCK**

Researcher: Stroma is correct yes.

Learners: Lamella. (learning context)-**ePCK**

Researcher: Lamella is correct yes. (pedagogical knowledge)-**pPCK**

Learners: Double membrane. (learning context)-**ePCK**

Researcher: Ribosome is correct yes.

Learners: Double membrane(learning context)-**ePCK**.

Researcher: Double membrane (pedagogical knowledge)-**pPCK** is correct yes. Starch grain is it correct? Is it correct or you're not sure? (pedagogical knowledge)-**cPCK**

Learners: Correct.

Researcher: It's correct neh. And the granum is also correct. So, if your drawing is correct, if everything is there then it means you're getting five over five. Now you can say yes.

Learners: Yes.

Researcher: We are done thank you.

APPENDIX 12: Lesson Observational Transcript from school 3 for lesson 1.

Zandaya: Okay what do you see in this picture(SAMR)? (pedagogical knowledge)-**cPCK**

Learner 1: *Inaudible.*

Zandaya: OK, you see a bunch of trees that is covered by? (pedagogical knowledge)-**cPCK**

Learner 2: *Inaudible.*

Zandaya: OK, bunch of trees that is covered by the leaves. OK, yes.

Learner 2: Uh Ma'am I see jungle that serves as a shelter for other organisms that live there…*inaudible*…(knowledge of the learners)-**ePCK**

Zandaya: You see a jungle that serves as a shelter for other organisms that lives there neh and also for food. OK.

Learner 3: I see green plants or trees which the exchange of gases will occur whereby uh will release carbon dioxide then um (knowledge of the learners)-**ePCK** …*inaudible*…

Zandaya: You can't say anything about gaseous exchange. I just want observable reasons give a visible. I am not saying you're wrong, but I wanted a visible reason neh so trees yes that's what you see as you also mentioned that you see green plants, so your answers are correct yes, the last person.

Learner 4: Um it looks like there are long trees in the picture(SAMR), in this picture and the second one it looks like it's the same thing and then they are green (knowledge of the learners)-**ePCK**

Zandaya: Oh, they are green. OK, so now eh we… someone mentioned that we see plants rights. And these plants are green right and uh we've learned in grade 8 about plants right, so before we get to the topic, I want us to first understand eh why these plants are green so let's just go back from grade 8 yes (content knowledge)-**cPCK**

Learner 5: They have a green pigment called chlorophyll to trap sunlight. (knowledge of the learners)-**ePCK**

Zandaya: They have a green pigment called chlorophyll to trap sunlight (pedagogical knowledge)-**ePCK** and where is this chlorophyll located? (pedagogical knowledge)-**cPCK**

Learner 5: In the chloroplast (knowledge of the learners)-**ePCK**

Zandaya: It is located in the chloroplast of what? (pedagogical knowledge)-**cPCK**

Learners: Of the plant (knowledge of the learners)-**ePCK**

Zandaya: Chloroplast of the? Where is chloroplast located in in the plants? Because you can't say plant. Someone says in the cells. Where specifically? (pedagogical knowledge)-**cPCK**

Learners: In the leaves, in the mitochondria (knowledge of the learners)-**ePCK**

Zandaya: In the? (pedagogical knowledge)-**cPCK**

Learner 2: Mitochondria (knowledge of the learners)-ePCK

Zandaya: In the mitochondria? (pedagogical knowledge)-**cPCK**

Learners: Laughing.

Zandaya: OK wait, someone says in the mitochondria, someone says in the lea…in the cells. Yes let's hear.

Learner 4: In the leaves Ma'am (knowledge of the learners)-**ePCK**

Zandaya: In the? In the leaf guys. It's located not in the. A mitochondria it's something else, it's another organelle that is found within the cell of the living organisms and also it does play a huge role neh, but this will discuss it in the next topic which is known as cellular respiration. (content knowledge)-**pPCK** So now our topic now eh it is photosynthesis neh!. The topic esizofunda ngayo *(we gonna learn about)* today, it is known as the photosynthesis. So, let's try to break down before uh we get to know more about photosynthesis ukuthi *(that)* what uh, what is photosynthesis and what is the important of photosynthesis. So basically, what you need to know in this topic yes it is what is photosynthesis, right? What is the role of photosynthesis and where does this photosynthesis occurs, right. So, let's try to break down this terminology. Photosynthesis (Content knowledge)-**pPCK**. Who can break it down for us? (pedagogical knowledge)-**cPCK** We've learnt this in grade 8 so please let's just recall from what we have learnt.

Learner 6: Photo means light (knowledge of the learners)-**ePCK**

Zandaya: Photo, photo means light (pedagogical knowledge)-**ePCK** neh, photo means light, so meaning that a light plays a huge role in the process of photosynthesis (Content knowledge)-**pPCK**. So basically, photosynthesis it is a process neh that occurs in. It occurs where? (pedagogical knowledge)-**cPCK**

Learner 4: Green plants (knowledge of the learners)-**ePCK**

Zandaya: Where does photosynthesis occurs?(pedagogical knowledge)-**cPCK**

Learners: In green plants (knowledge of the learners)-**ePCK**

Zandaya: In green plants (pedagogical knowledge)-**ePCK**, right specifically in the leaves. Then we will get to know how does this process takes place then what is synthesis? Then what is to synthesize, synthesis? Synthesis it means what? (pedagogical knowledge)-**cPCK**

Learner 6: Manufacture (knowledge of the learners)-**ePCK**

Zandaya: Synthesis it means what? (pedagogical knowledge)-**cPCK**

Learner 6: Manufacture (knowledge of the learners)-**ePCK**

Zandaya: It means to manufacture (pedagogical knowledge)-**ePCK**. Why ingabhali manje *(is it not writing)* this thing? Highlighter, this one is not visible, let's try that. What is to synthesise? To manufacture neh, is to manufacture. Yah neh. Weehh.

Learner 6: Lesi siyajema *(this one breaks off)*.

Zandaya: Siyajema *(it breaks off)*? Uyabona izinkinga esinazo *(do you see the challenges we have)*? Where am I? my pen. Okay. So, manufacture neh. So, by manufac… in life sciences, we say we manufacture neh, but in simple English to manufacture is to make something, right. So, in this process, what is it that basically that is made from this process cause we say that photosynthesis we saying that it is light neh, we see light and we see synthesis. Which is the process of manufacturing (Content knowledge)-**pPCK**. What is it that is being manufactured? Is it the light? (pedagogical knowledge)-**cPCK**

Learners: No.

Zandaya: It's what? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Zandaya: What is it that is being manufactured here? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Zandaya: Oxygen (pedagogical knowledge)-**ePCK** is being manufactuc…? What is that is manufactured? The end process? (pedagogical knowledge)-**cPCK**

Learners: To make (knowledge of the learners)-**ePCK**

Zandaya: Yes.

Learners: Glucose (knowledge of the learners)-**ePCK**

Zandaya: Definitely glucose (pedagogical knowledge)-**ePCK** neh. Glucose it is the one being manufactured (Content knowledge)-**pPCK** Then how does the oxygen plays a role here? Someone mentioned oxygen, that the oxygen is being manufactured. iGlucose guys, let's remember. Let's, Asikhumbuleni asikhumbuleni *(let's remember let's remember)*. How does oxygen plays a role here, where does it enter? (pedagogical knowledge)-**cPCK**

Learner 3: Oxygen? (pedagogical knowledge)-**cPCK**

Zandaya: Yes

Learner 5: It has water (knowledge of the learners)-**ePCK**

Zandaya: It has water (pedagogical knowledge)-**ePCK**. Okay, ummh.

Learner 7: Oxygen has been taken out of the plant (knowledge of the learners)-**ePCK**

Zandaya: Taken out of the plant neh. So, is it eh is it the oxygen the by product or is it the eh eh end product of photosynthesis? (pedagogical knowledge)-**cPCK**

Learners: It's a by-product (knowledge of the learners)-**ePCK**

Zandaya: OK let's go back. By products and eh requirement neh remember ama requirement izinto ezidingakalayo *(are things that are neded)*_right. Requirements of photosynthesis. Then sinama *(we have)* by-products of photosynthesis right. So, the requirements are things that I needed in order for photosynthesis to occur, right. Then ama by-products it's what is being um, it is the end-product of photosynthesis. So yes, glucose and oxygen, those are the products of photosynthesis. So basically, today we're just going to how is this glucose manufactured? And how is this oxygen released in the atmosphere because we know that oxygen it is an important gas and we need in order to sustain life neh. So, even mesenza icellular respiration we, grade 9 you've done it, you will know how is this oxygen play a huge role in photosynthesis (Content knowledge)-**pPCK** OK, so let's try, lets, ngicel ning'ph *(please give me)* a full definition now of photosynthesis before we get to the things. Who can like give us a definition of photosynthesis? (pedagogical knowledge)-**cPCK** Yes eh learner 5.

Learner 3: The process um, whereby where green plants and some other organisms use sunlight to uh side to side, synthesise nutrition from the carbon dioxide (content knowledge)-**cPCK**

Zandaya: Start afresh, it's what? (pedagogical knowledge)-**cPCK**

Learner 3: The process by which green plants and some other organisms use sunlight to synthesis the the nutrients from carbon dioxide and water (knowledge of the learners)-**ePCK**

Zandaya: Um, OK. Another one. We'll get to that, yes.

Learner 5: Photosynthesis is the process whereby green plants produce their own food using sunlight energy and water to produce o to produce oxygen and (knowledge of the learners)-**ePCK** …

Zandaya: Khona la eku lackha khona *(there's something lacking)*, not really to produce oxygen. Yes.

Learner 2: Photosynthesis is the process which chlorophyll in the chloroplast of the green plant…*inaudible*…(knowledge of the learners)-**ePCK**

Zandaya: Chlorophyll in the chloroplast of the green plant does what? (pedagogical knowledge)-**cPCK**

Learner 2: Absorbs radiant energy from the sun, carbon dioxide from the atmosphere…*inaudible* (knowledge of the learners)-**ePCK**

Zandaya: OK, that's hundred percent correct neh. OK, so basically, guys when you write idefinition ye photosynthesis I don't want to say eh you saying that…you're on grade 11s now that photosynthesis is the process whereby plants manufacture their own food. Do not stop there neh. It is the process you've learnt that in grade 8 but now in grade 11 now singena deeper neh so when for, for example ukuze ukwazi uku explaina *(for you to be able to explain)* the photosynthesis you think of the requirements and also you think of the end-products, right. So, let's start with the requirements so that you can get a full definition of what? Of photosynthesis. So, eh what are the requirements of photosynthesis? What is it that you see in the picture(SAMR)? (pedagogical knowledge)-**cPCK**

Learner 7: Radiant energy (knowledge of the learners)-**ePCK**

Zandaya: So, what is this? (pedagogical knowledge)-**cPCK**

Learners: Water (knowledge of the learners)-**ePCK**

Zandaya: Water (pedagogical knowledge)-**ePCK** neh.

Learner 3: Sunlight (knowledge of the learners)-**ePCK**

Zandaya: This is water, which O_2, H_2O. Mmm, sinenkinga nje *(we just have a problem)*. I just wanted ipencil. H_2O, OK, what else that you see here? (pedagogical knowledge)-**cPCK**

Learners: Radiant energy (knowledge of the learners)-**ePCK**

Zandaya: Radiant energy neh, (pedagogical knowledge)-**ePCK** radiant energy from where? Where does this radiant energy come from? (pedagogical knowledge)-**cPCK**

Learners: Sun (knowledge of the learners)-**ePCK**

Zandaya: Definitely from the sun (pedagogical knowledge)-**ePCK** neh. OK, so the water and this radiant energy these are the requirements for photosynthesis neh. OK, then how does the water plays a role in photosynthesis? Lamanzi lawa aw ayenzani *(what does this water do)* in the process of photosynthesis? Why they are needed? Water? When photosynthesis takes place lamanzi kwenzakalani ngawo *(what happens to this water)*? (pedagogical knowledge)-**cPCK** Are they being absorbed, or they being taken out? Yes. Singekafiki lapho *(before we arrive* *there*), lapho singe… angifuni singene kakhulu *(I don't want us to get deeper).* So, basically what here just in simple nje water, water is needed because eh the plants they need to reabsorb water neh remember in in in in in grade 10 we've learned about uh the tissues that absorb this water from the, from the ground, right. Um im imvula mayinetha amanzi ayaphansi angisho *(when it rains the water goes to the ground)* from the ground. Then this water needs to be to be absorbed neh. Need to be transported to, to the leaves cause remember that photosynthesis it takes place in the? In the leaves angisho, so this water will be reabsorbed by what? (pedagogical knowledge)-**cPCK** Type of tissues we've done them ku biodiversity of…

Learner 3: Xylem (knowledge of the learners)-**ePCK**

Zandaya: Definitely it's the xylem (pedagogical knowledge)-**ePCK** angisho. So, the xylem is the one that will reabsorb this water from the ground (Content knowledge)-**pPCK** then it will be taken to the? To the leaves. Then how does this radiant energy, the radiant energy plays a role in photosynthesis? (pedagogical knowledge)-**cPCK** Yes.

Learner 7: It will be trapped by the green pigment which is chlorophyll and (knowledge of the learners)-**ePCK** …

Zandaya: Uh mm, definitely is se its going to be trapped by the? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll (knowledge of the learners)-**ePCK**

Zandaya: By the chlorophyll (pedagogical knowledge)-**ePCK** neh, chlorophyll which is the green pigment angisho *(right)* in order for photosynthesis to take place. Ok, so these are the requirements uh and these are the products of i iphotosynthesis which is oxygen but obviously you're going to learn about this, the entire process masesenza *(when we do)* eh the light phase and the dark phase, right (Content knowledge)-**pPCK**. OK, so I have already, already I mentioned this ukuthi (*that)* eh in biodiversity we've learned ukuthi ama *(that the),* we've learned we've learned that the plants they fall under this kingdom which is kingdom? Kingdom plantae neh. Then now we see that, we see the term eukaryote. Who can tell us what is the eukaryote? Why these plants regarded as a eukaryote? What does it mean? (pedagogical knowledge)-**cPCK**

Learner 9: It means that the plants contain many cells (knowledge of the learners)-**ePCK**

Zandaya: Because? (pedagogical knowledge)-**cPCK**

Learner 9: They contain many cells (knowledge of the learners)-**ePCK**

Zandaya: They contain many cells (pedagogical knowledge)-**ePCK** and in life sciences what do we call that? We call it the? They are? (pedagogical knowledge)-**cPCK**

Learners: Multicellular (knowledge of the learners)-**ePCK**

Zandaya: They are multicellular neh, multicellular (pedagogical knowledge)-**ePCK**. So, ama eukaryotes are organisms that are multicellular. So, iplant nayo its multicellular meaning that it is composed of many many cells neh (Content knowledge)-**pPCK**. Then what, what is the term eukaryote mean? Multi means many life science. Multi means many. Uni means? (pedagogical knowledge)-**cPCK**

Learners: One.

Zandaya: Uni means one (pedagogical knowledge)-**ePCK** neh. OK, then ama, what are autotrophs? (pedagogical knowledge)-**cPCK**

Learner 7: Autotrophs (knowledge of the learners)-**ePCK**

Zandaya: Autotrophs (pedagogical knowledge)-**ePCK**. Sorry, autotrophs.

Learner 7: They produce their own food (knowledge of the learners)-**ePCK**

Zandaya: Learner 10 what are autotrophs? (pedagogical knowledge)-**cPCK**

Learner 10: Organisms that are able to manufacture their own food (knowledge of the learners)-**ePCK**

Zandaya: Yes organisms that are able to manufacture (pedagogical knowledge)-**ePCK**, they can manufacture yebo,

Learner 10: Shembe!

Zandaya: What does Shembe mean guys? Yini ishembe vele *(what is shemebe)?* Yini ishembe? What is Shembe? Ma'am uyayazi ishembe ukuthi isho ukuthini *(do you know what does shemebe mean)*? OK, OK, so ama autotrophs, auto it comes from the word automatic meaning they can manufacture their own food unlike us. Thina us as human beings we fall under which? (pedagogical knowledge)-**cPCK**

Learners: Heterotrophs (knowledge of the learners)-**ePCK**

Zandaya: Heterotrophs (pedagogical knowledge)-**ePCK** because we can, we can't manufacture our own food. And who can give us a reason why us as humans we can't manufacture our own food? Because? (pedagogical knowledge)-**cPCK**

Learner 5: We don't have a green pigment.

Zandaya: Because we don't have a green pigment (pedagogical knowledge)-**ePCK** which is known as the? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll (knowledge of the learners)-**ePCK**

Zandaya: Which is known as the chloroplast neh.

Learners: Yes.

Zandaya: Chloro chlorophyll, sorry, chlorophyll. Any guys, any questions before I move? (pedagogical knowledge)-**cPCK**

Learners: No.

Zandaya: Any questions? Any confusion? (pedagogical knowledge)-**cPCK**

Learners: No.

Zandaya: Oh, we sorted? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Zandaya: OK, so basically, this is the structure of the plant. This is the external structure angeke ngingene kakhuku lana *(I won't get deeper)*. This is the internal structure of the? Of the plant. External and the internal structure (Content knowledge)-**pPCK**. We've done this in grade, in grade 10 neh. So, let's just go back kancane *(a little)*, angeke ngingene deep *(I won't get into it deeper)* but I want you to tell me ukuthi where are basically the chloroplast located here? So, basically there's an epidermis neh which is a layer eh this one. OK asibuyeleni emuva *(let's go back)*, epidermis, who can tell us the function because we do have epidermis in grade

11 and we spoke about it. (content knowledge)-**cPCK** It's the outermost layer, epidermis and what does it do there? (pedagogical knowledge)-**cPCK**

Learner 3: It protects the leaf…*inaudible*…(knowledge of the learners)-**ePCK**

Zandaya: It protects what? (pedagogical knowledge)-**cPCK**

Learner 3: The leaf that ensures that water is sufficient (knowledge of the learners)-**ePCK**

Zandaya: It protects the leaf OK. Not really the leaf but it does protect something. What does it protect? The epidermis? Insi inside inside this inside this structure as you can see inside the leaf kunama underlying tissues. Kunama, for example, xylem is a tissue, a phloem is a tissue, right. So, these underlying tissues they are protected by the epidermis (content knowledge)-**cPCK**. So, wena as a human being what protects, what protects the underlying tissues outside? (pedagogical knowledge)-**cPCK**

Learners: Skin (knowledge of the learners)-**ePCK**

Zandaya: Definitely the skin (pedagogical knowledge)-**ePCK** but under the skin also us as humans we do have epidermis that uh eh protects underlying tissues. Same applies to the structure neh. Then here kunama *(there's)* palisade mesophyll and the spongy mesophyll (Content knowledge)-**pPCK**. So, here in the palisade mesophyll what is it that is found mostly? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast (knowledge of the learners)-**ePCK**

Zandaya: Chloroplast (pedagogical knowledge)-**ePCK** neh, yes the chloroplast are found…

Learner 4: Ma'am its the chloroplast not the chlorophyll right? (knowledge of the learners)-**ePCK**

Zandaya: The chloroplast, (pedagogical knowledge)-**ePCK** yes. So, the chloroplast are found here in the palisade mesophyll most of them. Even naku spongy mesophyll akhona but they are not a lot as the, as the palisade mesophyll. So, it it means that i imm this eh photosynthesis it takes place where? Does takes, does take place here because there is the presence of? There is a presence of the chloroplasts neh but I'm not going to dwell much on this. OK, so guys this is the structure of the chloroplast. Ehmm, let's just look at the structure. So, this is microscopic neh, this was taken under the microscope cause remember that since chloroplast is found in the cells we cannot see ama cells with our naked eyes, right. OK so, this is just the structure ehmmm asiqale la (Content knowledge)-**pPCK**. There's an inner membrane neh. Asiqale la ku *(let's start here at)* outer membrane, let's start with the outer. What is, who can tell us what is the function of the outer membrane of the chloroplast mowucabanga *(when you think)?* Outer membrane? Definitely, guys ama membranes. Guys ngihlezi ngisho ukuthi *(I always say that)* the function of the membrane is either it's for protection and also to allow easy diffusion and remember diffusion must take place neh. So, there's a new term that you have learnt now which is known as a diffusion. Who can tell us what is diffusion? (pedagogical knowledge)-**cPCK** Mmm hmm?

Learner 5: It's the movement of air from highest concentration to the lowest concentration. (knowledge of the learners)-**ePCK**

Zandaya: Is the, is the movement of air, that air is known as what? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Zandaya: It is known as oxygen (pedagogical knowledge)-**ePCK** neh. From highest or lowest concentration? (pedagogical knowledge)-**cPCK**

Learners: Highest.

Zandaya: From highest (pedagogical knowledge)-**ePCK** concentration to its lowest concentration. So, idiffusion is not only about the transportation of air. Any substances neh.

Learners: Yes.

Zandaya: So, even na naka *(in the)* in the next uh following topic we are going to talk about the diffusion. So, basically diffusion it's the movement of substances from highest concentration to its lowest concentration. So, remember ukuthi *(that)* inside the cell of the plant oxygen is (Content knowledge)-**pPCK** …which which one moves inside eh eh the plant? (pedagogical knowledge)-**cPCK** Now now let's go to the plants.

Learners: Carbon dioxide (knowledge of the learners)-**ePCK**

Zandaya: Carbon dioxide neh (pedagogical knowledge)-**ePCK**. So, this carbon dioxide is the one that will diffuse, so the carbon dioxide is the one that will diffuse. Carbon dioxide…

Learner 7: Shembe.

Zandaya: Yazi ushembe lo straight. OK, awa. Uyabona ukuthi *(do you see that)* as teachers we do need itraining for these neh.

Learners: Yes.

Zandaya: Cause if, these are the problems esinawo la. We do need training for these, pen neh. Carbon dioxide, yes. Awa! Khona la egiprese khona *(where I'm pressing)*. OK, let's start afresh. Pen neh

Learners: Yes (*laughing*).

Learner 10: Presa emas'phakathini *(press in the middle)* Ma'am.

Zandaya: Discard, neh. Konje Ma'am singenephi lesas'khathi *(where do we put the time)*?

Researcher: Lapha phezulu *(on top).*

Zandaya: Ngiyithole ebunzimeni lento le *(it wasn't easy to find this thing)*. OK, yenza ifull screen *(make it a full screen),* yes. Siyithole lah *(we found it here),* siyithole somewhere la. OK, while while we are still fixing this guys eh idiffusion as we've said that icarbon dioxide is the one that will disuse angisho *(right)*

Learners: Yes.

Zandaya: Will diffuse into the leaf because it is more needed in the leaf in order photosynthesis to take place angisho *(right)* (Content knowledge)-**pPCK***)*. Then what is it that will move from the leaf to the atmosphere? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Zandaya: Definitely oxygen. So, meaning that carbon dioxide will diffuse from the atmosphere because it is a lot there, neh. It's going to diffuse into the leaf because in the leaf there is less carbon dioxide. So ,eh that is the process which is known as idiffusion (Content knowledge)-**pPCK**. Seyishap manje? *(is it fine now?)* OK. So, as I've said that the outer membrane, what will happen? Diffusion will take place neh. Sengisaba nokupressa izovele icisheke *(I'm even scared to press it, it will just switch off)*. Oh! we have it here again. This is nice, OK. Why? Why it does this? (pedagogical knowledge)-**cPCK**

Learner 3: Soze sibhale ebhodini *(we will end up writing on the board).*

Zandaya: Hhayi kumele sibhale la cause *(we must write here)* we are using what? Smartboard. Angisho anginane marker neh *(plus I don't even have a marker),* so we must use this. OK, so basically, what will happen here, this carbon dioxide that is accumulated in the atmosphere will diffuse neh. Will diffuse here into the chloroplast. Ok, then what is the function of, let's go to the ama ama thylakoid (Content knowledge)-**pPCK**. Do you see the the thylakoid? Niyawazi ama *(do you know)* pan cakes? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Zandaya: So, it's like a stack neh. Ziyanamathelane *(they stick to each other)* so it's known as thylakoid. Then eh i. who can tell us what is the function of the thylakoid? What is happening there in the thylakoid? (pedagogical knowledge)-**cPCK** Remember.

Learner 6: That's where the light phase take place (knowledge of the learners)-**ePCK**

Zandaya: Yes, sizokhuluma nge *(we will talk about)* light phase and the dark phase neh, OK. So, it does not it does not necessarily happen in the thylakoid. Where does the light phase takes place? So, but angifuni sikhulume nge *(I don't want us to talk about)* light phase manje because remember that khona ababaphambili *(there's those who are forward)* neh. Eh, we have to know first what is the light phase. So, we cannot talk about the light phase esithubeni *(out of no where).* So, in the gra…OK we will we will get to that cause I have to explain the light phase before sizokhuluma ngama functions neh. But here this is just the…*inaudible*….structure of the, of the chloroplast. So, this is where you find, so when you get to the light phase and dark phase we are going to talk more about this, more about these structures neh. So, now we have a new term which is known as a light phase and the dark phase (Content knowledge)-**pPCK**. Who can tell us ukuthi yini *(what is)* ilight phase? Yini idark phase? (pedagogical knowledge)-**cPCK** There's a light phase; there's a dark phase. So, let me just give you an ideas that eh uzokwazi ukhuluma ngani *(so you'll know what you're talking about)*. So, mes'khuluma nge *(when we talk about)* light phase, so iphotosynthesis takes place into two processes neh. In order for eh plants, in order for food to be manufactured two processes must take place. The first phase is the light phase, light-dependent neh. Light-dependent phase and the second one is the light-dependent phase slash dark phase neh. Light phase and the dark phase. So, the light phase and the dark phase both of them they make this entire process of photosynthesis. So, at least I gave you an idea, (Content knowledge)-**pPCK** who can tell us keh ukuthi yini ilight phase? Mmm? Light phase, dark phase any idea masesikhuluma nge *(when we talkin about)* light phase? (pedagogical knowledge)-**cPCK** I gave you an eh eh eh idea. Light phase meaning that it is a dependent, there's something that is dependent on the light. This photosynthesis is dependent of the light.

Learner 6: *Inaudible.*

Zandaya: Yes meaning that photosynthesis occurs in the presence of light. Iyazisho light-dependent phase, meaning that in order for photosynthesis to take place it depends on the light to occur. What about the light-independent phase which is known as the dark phase? (pedagogical knowledge)-**cPCK**

Learner 3: It occurs in the absence (knowledge of the learners)-**ePCK**

Zandaya: Occurs in the absence of light neh. OK, so this is basically eh the structure that shows the process of the light phase neh(Content knowledge)-**pPCK**. Want some ideas, just, I'll just give you a minute just to look at this structure. Then then uzos'tshela ukuthi kwenzakalani la *(you'll tell me what's going here)*. So, niyabona le grana benginitshengisa yona *(do you see the grana I was showing you)*? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Zandaya: So, this is where this light phase takes place neh. Takes place not in the thylakoid, does not take place in the thylakoid (Content knowledge)-**pPCK**. Takes place in the? (pedagogical knowledge)-**cPCK**

Learners: Grana (knowledge of the learners)-**ePCK**

Zandaya: In the grana. So, since i this light phase takes place in the grana what does, what does this mean? What is it that is eh found in the eh, in the in the grana? Kutholakala ini *(what do we find)*? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast (knowledge of the learners)-**ePCK**

Zandaya: Kutholakala ini *(what do we find)*? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast (knowledge of the learners)-**ePCK**

Zandaya: Ini? (pedagogical knowledge)-**cPCK**

Learner 3: Chlorophyll (knowledge of the learners)-**ePCK**

Zandaya: So, we saying that we saying that the the light-dependent phase neh. The light phase takes place in the grana of the of the chloroplast(Content knowledge)-**pPCK**.

Learner 3: Yes.

Zandaya: So, what does this tell you if masithi *(when we say)* this light-dependent phase it happens in the in the grana? Yes. What is it that is there? What is it that is there? (pedagogical knowledge)-**cPCK** Yes.

Learner 11: Water (knowledge of the learners)-**ePCK**

Zandaya: Mmm umm, there is no water there. What is it that is there that enables this process to occur? (pedagogical knowledge)-**cPCK** Guys siyishilo lento le.

Learner 4: Chlorophyll (knowledge of the learners)-**ePCK**

Zandaya: Yes, definitely meaning that the chlorophyll is found there in the grana angisho *(right!)*. Is located there because now if photosynthesis can take place in the grana so meaning that there is a presence of the, of the chloroplast oh I mean of the chlorophyll (Content knowledge)-**pPCK**. And this entire process takes place in the? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast (knowledge of the learners)-**ePCK**

Zandaya: In the chloroplast. You must know the difference. Chloroplast it is the site for photosynthesis, then the chlorophyll it is the green pigment that traps what? (pedagogical knowledge)-**cPCK** Traps the radiant energy neh. So, who can explain what is it that is happening here? Areboweng *(let's talk)*. Nangu number one, what is what is number one? (pedagogical knowledge)-**cPCK**

Learners: It's radiant energy (knowledge of the learners)-**ePCK**

Zandaya: What do you call it? (pedagogical knowledge)-**cPCK** Number one.

Learners: Radiant energy (knowledge of the learners)-**ePCK**

Zandaya: What do you call it? (pedagogical knowledge)-**cPCK**

Learners: Sun (knowledge of the learners)-**ePCK**

Zandaya: We call it we call it the sun. It is the sun neh, mesingabeka umntwana kagrade 8 sithi yini le uzothi yilanga neh *(if we were to place a grade 8 learner and ask the learner what this is, the learner will say it's sun).* So, le radiant energy eniyibonayo la *(that you see here)* meaning that when photosy when light phase takes place this is the process that needs to occur neh. So, number one so this diagram(SAMR) it makes things easy. So, this is, there's number one here (Content knowledge)-**pPCK**. So, we say that what we're seeing is the? (pedagogical knowledge)-**cPCK**

Learners: Sun (knowledge of the learners)-**ePCK**

Zandaya: Is the sun angisho *(right)*. Then there's number two. Number two is this grana neh.

Learners: Yes.

Zandaya: Then number three, OK let's explain the process there. Let's start with number one, number two.

Learner 8: Radiant energy is being absorbed (knowledge of the learners)-**ePCK**

Zandaya: Sithe sithe sithe ku grana sithola ini? *(we said we said we said in the grana we find what?)* (pedagogical knowledge)-**cPCK**

Learner 4: Chloroplast (knowledge of the learners)-**ePCK**

Zandaya: Sithola ini *(we find what)*? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll (knowledge of the learners)-**ePCK**

Zandaya: iChlorophyll (pedagogical knowledge)-**ePCK**. Then this chlorophyll that is found here so here we get the chlorophyll angithi. Sithola ichlorophyll which is the green pigment. That's why ama plants agreen. Which is known as a green pigment neh (Content knowledge)-**pPCK**. Eh, then if now we get chloroplast what will happen here? Kwenzakalani (what's happening)? Let's just, just explain mowucabanga nje ucabangani *(what are you thinking)*? Yes. (pedagogical knowledge)-**cPCK**

Learner 12: Um, the radiant energy is going to be absorbed by the chlorophyll in the grana along with water (knowledge of the learners)-**ePCK**

Zandaya: What? (pedagogical knowledge)-**cPCK**

Learner 12: Along with water (knowledge of the learners)-**ePCK**

Zandaya: Ok nawa amanzi *(here's the water)* H_2O angisho la *(here right!)*

Learners: Yes.

Zandaya: So, meaning what will happen here? As she explained is that the chlorophyll niyabona nonke angisho *(you'll can see right)*? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Zandaya: The chlorophyll will do what? (pedagogical knowledge)-**cPCK** Will absorb the radiant energy and the water, right

Learners: Yes

Zandaya: Then what will happen after? So, there's number three. What, what is it that's happening here in number three? Who can tell us? (pedagogical knowledge)-**cPCK** Yes.

Learner 3: The radiant energy cause cause the water to split ….*inaudible*…(knowledge of the learners)-**ePCK**

Zandaya: Yes, definitely any process that takes place energy is needed neh. So, this energy, since now this radiant energy is being absorbed it will cause this H_2O to? To split angisho *(right)?* So le H_2O le H_2O it is composed of what? (pedagogical knowledge)-**cPCK**

Learner 11: Oxygen and hydrogen (knowledge of the learners)-**ePCK**

Zandaya: H, I think akumelanga ngibhale la shame. Ingipha iproblem *(I think im not supposed to write here, it's giving me problems).* OK, sine H_2O angithi, H_2O is composed of what? (pedagogical knowledge)-**cPCK**

Learners: Hydrogen and oxygen (knowledge of the learners)-**ePCK**

Zandaya: Hydrogen and? Oh, how many hydrogens? (pedagogical knowledge)-**cPCK**

Learners: Two (knowledge of the learners)-**ePCK**

Zandaya: Two hydrogen and oxygen neh! H_2O. so, what will happen here, remember ukuthi this entire process takes place in the? In the? (pedagogical knowledge)-**cPCK**

Learners: Chloroplast (knowledge of the learners)-**ePCK**

Zandaya: Takes place in the grana neh. This entire process esizobe siyi explaina la *(the process that we will be explaining)* it takes place in the? (pedagogical knowledge)-**cPCK**

Learners: In the grana (knowledge of the learners)-**ePCK**

Zandaya: In the grana (pedagogical knowledge)-**ePCK** and the grana is found in the chloroplast. So, this entire process the site is the chloroplast neh. OK, so basic what will happen here as you can see now eh this grana, there's a chlorophyll angisho. It will absorb the radiant energy and then even water will be reabsorbed angisho amanzi ayangena la *(the water enters here)* (Content knowledge)-**pPCK**. Then number three there's a process that takes place here and it is known as what? What is the name of the process? It's a photolysis neh, it's a photolysis then meaning that the split of hydrogen and what? (pedagogical knowledge)-**cPCK**

Learners: And oxygen (knowledge of the learners)-**ePCK**

Zandaya: And oxygen they will split neh. Then after, mowuceda uku splita *(after splitting)* what will happen to the oxygen? What will happen to the oxygen? (pedagogical knowledge)-**cPCK**

Learner 1: It will be released (knowledge of the learners)-**ePCK**

Zandaya: Will be released neh

Learners: Yes.

Zandaya: Through what? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Zandaya: Lama pores esiwa *(that we)* a a a aphumayo *(that are coming out)* a ama ioxygen mayiphuma siyibiza ngani *(when the oxygen goes out)*? (pedagogical knowledge)-**cPCK**

Learner 5: Stoma (knowledge of the learners)-**ePCK**

Zandaya: Ye? (pedagogical knowledge)-**cPCK**

Learner 5: Diffusion (knowledge of the learners)-**ePCK**

Zandaya: No, not diffusion. What allows for this oxygen to move out? (pedagogical knowledge)-**cPCK** Yes.

Learner 5: Guard cell cells of the stoma (knowledge of the learners)-**ePCK**

Zandaya: Yes, of istoma neh, is it? Is it? Ma'am is it a stoma or a stomata? (pedagogical knowledge)-**cPCK**

Learners: Stomata.

Zandaya: Yes it is a stomata not the stoma guys (content knowledge)-pPCK. Stomata, yes, it's a stomata neh. Not the stoma, stomata. So, the stomata will allow these uh oxygen oxygen to be? To be released and this oxygen will go where? (pedagogical knowledge)-**cPCK**

Learner 3: To the atmosphere (knowledge of the learners)-**ePCK**

Zandaya: Will go in the… Definitely in the atmosphere neh because uyayidinga *(you need it).* The next next next for the next topic you will understand ukuthi le oxygen njengoba iya *(when it goes)* outside, you still need it as a human being because cause remember that this is a? This is a plant. Then with his hydrogen will play a huge role in the? In the dark phase neh we carried it from the granum it goes to the? (pedagogical knowledge)-**cPCK**

Learners: Stroma (knowledge of the learners)-**ePCK**

Zandaya: Stroma, this is where dark phase takes place angisho. Em, ziphi lezinto futhi? *(what are those things again)* Smartboard sala sesine internet siyasala thina e classin lethu. OK, the the next process that will take place is after ilight phase it is known as the dark phase neh. As we have mentioned that the dark phase takes place in the absence of the? Absence of the? (pedagogical knowledge)-**cPCK**

Learners: light (knowledge of the learners)-**ePCK**

Zandaya: Absence of the light neh. Hence we call it the light and izimele *(it's standing on its own)* neh. Like uMa'am u independent angisho *(right)* and you, you are the light dependent phase cause you depend on uMa'am 3 ane (pedagogical knowledge)-ePCK.

Learners: Yes.

Zandaya: Mina I'm light independent. So idark phase we call it light independent meaning that it does not need light in order for photosynthesis to take occurs, to take place neh. OK, so even this structure its easy guys iyazisho. OK neh, light-independent, so eh anyone just look at the structure and tell us what is happening here (Content knowledge)-**pPCK**. Now we see number one, what is it that is happening in number one? (pedagogical knowledge)-**cPCK** Yes.

Learners: Carbon dioxide enters (knowledge of the learners)-**ePCK**

Zandaya: Carbon dioxide enters neh. So, this process it is known as the difuision, diffusion because this carbon dioxide it moving from its highest concentration to its lowest concentration where it is needed (Content knowledge)-**pPCK** Then this carbon dioxide will diffuse through the? (pedagogical knowledge)-**cPCK**

Learner 9: Stroma (knowledge of the learners)-**ePCK**

Zandaya: Through through the

Learner: Stomata (knowledge of the learners)-**ePCK**

Zandaya: Ngithe ungakhulumi nge stroma *(I said don't talk about the stroma).* Stomata stomata ende *(and)* this entire process takes place in the? (pedagogical knowledge)-**cPCK**

Zandaya and the learners: Stroma.

Zandaya: Ayikho into abathi yistroma neh *(there is nothing called stroma).* Stroma, stroma it is the site of? (pedagogical knowledge)-**cPCK**

Learner 5: The chloroplast (knowledge of the learners)-**ePCK**

Zandaya: Awa, site of the dark phase. It is the site of the dark phase. This light-independent phase neh. This is where it takes place. Then carbon dioxide obviously will diffuse from the atmosphere neh, it will diffuse from the atmosphere into the leaf through the? Through the? (pedagogical knowledge)-**cPCK**

Learner 3: Through the stomata (knowledge of the learners)-**ePCK**

Zandaya: Yah kuyomel ukthi ngi *(I have to)* emphasize ngoba ku *(because in the)* exam nizobe nibhala kanje *(you'll be writing like this)* through the stomata neh. Nayi iyagena lana, carbon dioxide. Remember ukuthi where does this H comes from? (pedagogical knowledge)-**cPCK**

Learner 5: From the water (knowledge of the learners)-**ePCK**

Learner 11: From the H_2O (knowledge of the learners)-**ePCK**

Zandaya: From the H_2O (pedagogical knowledge)-**ePCK** Remember that it was transported neh (Content knowledge)-**pPCK**

Learners: Yes.

Zandaya: To the? To the stroma then this carbon dioxide will then combine with? (pedagogical knowledge)-**cPCK**

Learner 7: With hydrogen.

Zandaya: With this hydrogen then eh then what is ATP guys? (pedagogical knowledge)-**cPCK**

Learners: Energy carrier (knowledge of the learners)-**ePCK**

Zandaya: It is known as the? (pedagogical knowledge)-**cPCK**

Learners: Energy carrier (knowledge of the learners)-**ePCK**

Zandaya: Ende sizokhuluma ngayo ku *(we will talk about it when we do)* cellular respiration. It is known as the? (pedagogical knowledge)-**cPCK**

Learners: Energy carrier (knowledge of the learners)-**ePCK**

Zandaya: And this, where is basically located? Where?, itholakala kuphi *(where do you find)* this ATP inside the cell?. (pedagogical knowledge)-**cPCK**

Learners: Uh light phase, dark phase (knowledge of the learners)-**ePCK**

Zandaya: Itholakala kuphi? *(where do you find it?)* Which which which which eh organelle? Which organelle is the cell? (pedagogical knowledge)-**cPCK**

Learner 3: Starch granule, starch granule (knowledge of the learners)-**ePCK**

Zandaya: Ini? (pedagogical knowledge)-**cPCK**

Learner 3: Starch granule (knowledge of the learners)-**ePCK**

Zandaya: Angikuzwa *(I can't hear you)…inaudible…*where? Guys imitochondria? Itholakala kuphi *(where do you find it)* in in the in the cell? (pedagogical knowledge)-**cPCK**

Learner 13: Mitochondria (knowledge of the learners)-**ePCK**

Zandaya: Mitochondria guys, mitochondria (pedagogical knowledge)-**ePCK.** OK then now what the process that will will take place here em em this carbon dioxide that we what that was reabsorbed will combine with with hydrogen (Content knowledge)-**pPCK** and combine with what? (pedagogical knowledge)-**cPCK**

Zandaya and the learners: ATP

Zandaya: To form? (pedagogical knowledge)-**cPCK**

Learners: Glucose (knowledge of the learners)-**ePCK**

Zandaya: To form glucose neh, to form iglucose.

Learners: Yes.

Zandaya: So, this glucose it is the food we have spoked about ukuthi *(that)* eh is the process whereby plants manufacture their own food. So, this is just a a what is already we spoke about. Just a diagram(SAMR) so this is just it's a chemical reaction neh (Content knowledge)-**pPCK**. Chemical reaction I mean, sorry, any questions guys before we move on. OK, so, icarbon dioxide it's what? It's a requirement or is a? and water, zibizwa ngani? *(what do you call them?)* (pedagogical knowledge)-**cPCK**

Learners: Requirements (knowledge of the learners)-**ePCK**

Zandaya: Requirements right., are known as…so when u Ma'am ask what are the requirements of photosynthesis is carbon dioxide and water and the end-product its what? Glucose will be formed angisho *(right)*. So, this sugars yi yiglucose. Eh these sugars is glucose right

Learners: Yes.

Zandaya: Then what do we release at the end? (pedagogical knowledge)-**cPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Zandaya: Oxygen (pedagogical knowledge)-**ePCK.** So, we call both of these we call this ama end product or by-products. Yes, are known as by-products. These are end results of photosynthesis. Niyabona mos noma kubhalwe kabi *(although the handwriting does not look good you can see right)* but these are the by-products neh. (Content knowledge)-**pPCK**

Learners: Yes.

Zandaya: By-products, these are the end result of iphotosynthesis. Are we sure guys ukuthi *(that)* eh you understood? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Zandaya: It's just a summary guys of what we already spoken about it. So, this is a cells structure, we've learnt about the cell in grade in grade 10 angisho *(right).* Then inside the cells this where we find this organelle, right. So, nayi ichlroro ichloroplast it is it is it is it is an organelle (Content knowledge)-**pPCK** neh. Then inside the chloroplast you find what? (pedagogical knowledge)-**cPCK**

Learners: Grana (knowledge of the learners)-**ePCK**

Zandaya: You find this this this chloro chlorophyll. Grana, and then this chloro chlorophyll siyithola kuphi *(where do we find it)*? Siyithola la ku grana ane *(we find it inside the grana).* Then, this'bone. Yah its just the entire process nje kuphela *(that's all)* (Content knowledge)-**pPCK**). akunamuntu ozofaila iphotosynthesis neh *(no one will fail photosynthesis).* No one will fail photosynthesis.

Learner 3: Kumele bayenze ibe *(they must make it)* 50 marks.

Zandaya: Ngiyenze ibenjani? *(how must I make it look like?)* (pedagogical knowledge)-**cPCK**

Learner 3: 50 marks.

Zandaya: Oh, the importance, what are the? significance means importance. What is the importance of photosynthesis? Who can tell us what is the importance of photosynthesis? (pedagogical knowledge)-**cPCK** Yes.

Learner 5: It plays the role to balance the chain the food chain (knowledge of the learners)-**ePCK**

Zandaya: To balance the food chain (pedagogical knowledge)-**ePCK**, what do you mean by that? (pedagogical knowledge)-**cPCK**

Learner 5: Um when green pigments, OK when the green pigments in the plants eh helps the plant to produce their own food the first consumers that consume the plant um basically it plays a significant role in photosynthesis (knowledge of the learners)-**ePCK**

Zandaya: OK asenzeni ifood chain *(let's make a food chain).* Let's do a food chain, so uthe wathi uthi wathi *(you said that)* the importance of iphotosynthesis is for ifood chain

Learners: Yes.

Zandaya: So, when let's draw a food chain. So, let's say we have a sun, ifood chain guys in grade 8 you sense *(we did)* ifood chain with this organisms neh! (content knowledge)-**cCPK**

Learners: Yes.

Zandaya: Always start with a producer neh. The producer is the sun, and what else? Let's just take out ama organisms here. What depend on the sun? (pedagogical knowledge)-**cPCK**

Learners: Plants.

Zandaya: Plants neh, so we can say a tree. Tree is a producer, actually a tree it's a producer. Sun's ray, so tree it's a producer (Content knowledge)-**pPCK**

Learner 4: Yes.

Zandaya: OK, the um what else from the diagram(SAMR) that you see? (pedagogical knowledge)-**cPCK**

Learner 13: Insects.

Zandaya: What what insects? (pedagogical knowledge)-**cPCK** Isho igama phela *(say it's name)*.

Learner 10: Asiyiboni *(we can't see it),* we can't see it.

Zandaya: OK, you can just name any insect that you know.

Learner 10: Caterpillar (knowledge of the learners)-**ePCK**

Zandaya: Caterpillar (pedagogical knowledge)-**ePCK** neh, caterpillar or intethe *(grasshopper).* Niyayazi intethe *(do you know a grasshopper)*? (pedagogical knowledge)-**cPCK**

Learners: Yes, No.

Zandaya: Aniyazi intenthe (you don't know a grasshopper)? (pedagogical knowledge)-**cPCK**

Learners: Siyayazi, yigrasshopper.*(we know it, it's a grasshopper)*

Zandaya: Niyazi ngani igrasshopper *(how do you know a grasshopper)?* Niyazi ngentethe *(you know it as grasshopper).* Ok, you can say grasshopper also neh. So, this arrow represents the flow of energy angisho. So, meaning that uh the tree all all the time, ithi ngicishe lana *(let me erase here)* actually. Let me just remove this side so that ungabi confused. So, all the time ifood chain you start with the, where's the eraser? You start with the producer neh. So, tree there's a caterpillar, what else? What is a caterpillar guys? (pedagogical knowledge)-**cPCK**

Learners: A bird.

Zandaya: Nisho? *(are you sure?)* (pedagogical knowledge)-**cPCK**

Learners: Yes.

Zandaya: What is the bird? What else? What is the bird? (pedagogical knowledge)-**cPCK**...*inaudible*…OK, so basically the point of doing this, so this is the importance of iphotosynthesis cause guys without the plants there's no life neh.

Learner 3: Yes.

Zandaya: Because other organisms depend on this plant in order to survive. So, it means ukuthi if ama *(that if the)* caterpillar they can get energy from the su from the trees meaning that ayakwazi ukuphila ayakwazi uku surviva angisho *(they can live, they can survive right).* Meaning ama bird they can feed on the caterpillars. Organisms that feed on the on the bird also the reason zizokwazi ukuphila *(so they can live)* is because the birds they get food from these organisms. So, if manje ama caterpillar anagafa or all the organisms that depend on trees then there is a problem in in in in the entire process of the food chain. Meaning that other organisms won't feed on these organisms neh. So, that's the first importance, yes to balance ifood chain. (Content knowledge)-**pPCK** What else? The importance of photosynthesis? Why? (pedagogical knowledge)-**cPCK**

Learner 6: For energy production (knowledge of the learners)-**ePCK**

Zandaya: It's for energy production, OK. Another importance. Yes.

Learner 14: To form the…*inaudible*…

Zandaya: Trophic levels, yizo zona lezi.*(these are the ones).*

Learner 5: To balance the air (knowledge of the learners)-**ePCK**

Zandaya: To balance the air. Does not really balance the air. What is it that is balanced?

Learner 5: Oxygen and carbon dioxide (knowledge of the learners)-**ePCK**

Zandaya: Yes the gases are balanced maintaining the balance angisho *(right)* cause remember that if there's too much carbon dioxide in the atmosphere its going to be toxic neh. We might end up dying, so this carbon dioxide, when plants reabsorb this carbon dioxide it balances the level of, the concentration of carbon dioxide in the atmosphere. And definitely we need oxygen angisho *(right),* so it gives us oxygen (Content knowledge)-**pPCK** So, trees gives us life eh. So, its for food, for maintaining balance. I think this is then end of the…ithi ngibone *(let me see).* So now what we are going to do guys is practical, but then siyenza ngama nge siyenza *(we do it with, we do it with)* visually…*inaudible*…but after here we're going to do i let's just do this activity. Nginipha i2 minutes (I'm giving you 12 minutes).

Leaners: Huh!

Zandaya: OK, we can do corrections mos (assessment knowledge)-**cPCK.**

Learners: Yes.

Zandaya: Are you all connected to iwifi? Cause kukhona umsebenzi esow'yenza *(because there's work that we'll do).* OK, lets just do quickly. Identify the phases, the only phases that we have la ay'2 neh. We have only two phases in photosynthesis. So, the first phase eh, phase number one, OK. So, the first phase it is what? (pedagogical knowledge)-**cPCK**

Learners: The light phase.

Zandaya: Definitely it's the light phase cause this is the first phase neh.

Learners: Yes.

Zandaya: This'bone (*let's see*), it is what? (pedagogical knowledge)-**cPCK**

Learners: Light phase (knowledge of the learners)-**ePCK**

Zandaya: Light phase neh, light dependent phase.

Learner 5: Yeka Ma'am.

Zandaya: Awa, ufun'ukukopa? Kunini nikopa *(you want to copy? How long have you been copying)*. Light phase then kwi…

Learners: Dark phase (knowledge of the learners)-**ePCK**

Zandaya: This is the dark phase angisho *(right)*? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Zandaya: OK provide eh the two raw materials labelled A and B. So, in order for this eh light phase to take place what is it that is needed? (pedagogical knowledge)-**cPCK**

Learner 3: Radiant energy (knowledge of the learners)-**ePCK**

Zandaya: So, 'A' it's what? (pedagogical knowledge)-**cPCK**

Learners: Radiant energy (knowledge of the learners)-**ePCK**

Zandaya: It's the radiant energy angisho *(right).*

Learners: Yes.

Zandaya: Then 'B' its what? (pedagogical knowledge)-**cPCK**

Learners: Water (knowledge of the learners)-**ePCK**

Zandaya: 'B' it's water. Why nithi amanzi lawa? *(why are you saying this is water)?* (pedagogical knowledge)-**cPCK**

Learner 3: Because its H_2O (knowledge of the learners)-**ePCK**

Zandaya: Why nithi *(why say)* H_2O? Why ningathi le *(why are you saying)* its H_2O? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Zandaya: There's a clue neh, its blue. OK, the A is the radiant energy that is needed, then B is H_2O neh. Name the by-product labelled as C. By-product, by-product (Content knowledge)-**pPCK**

Learners: Oxygen (knowledge of the learners)-**ePCK**

Zandaya: Definitely its oxygen or the end results of the dark phase. Which substance labelled as D is essential for photosynthesis? (assessment knowledge)-**cPCK**

Learners: Carbon dioxide (knowledge of the learners)-**ePCK**

Zandaya: It's what? (pedagogical knowledge)-**cPCK** Its carbon dioxide. OK, then um, name the product E.

Learners: Glucose (knowledge of the learners)-**ePCK**

Zandaya: OK name the product E that is produced during phase two.

Learners: Glucose (knowledge of the learners)-**ePCK**

Zandaya: Definitely glucose neh. Is glucose, in what form is stored in plants? (pedagogical knowledge)-**cPCK**

Learners: Starch (knowledge of the learners)-**ePCK**

Zandaya: Definitely is formed, it is stored as starch. Describe the role of raw material A. What is the eh the importance of A, the radiant energy? What is the importance? (pedagogical knowledge)-**cPCK** So, nawa ama *(here are the)* corrections (assessment knowledge)-**cPCK** neh. It plays a role in photolysis angisho *(right)*. Asenzeni ama ama *(let's make, let's make),* make sure that u… in order for photolysis to take place radiant energy is needed angisho *(right)* cause remember that eh i i.

APPENDIX 13: Lesson Observational Transcript from school 3 for lesson 2.

Researcher: Learners, uh listen neh. So, you just did the introduction to photosynthesis and Ma'am just explained to you the entire process neh. The definition, the organelle where it takes place, um the importance of photosynthesis and the light phase what happens in the light phase and what happens in the dark phase neh. So, now we're just gonna move on to one of the practical you know like everything that you do it has to involve the practical neh. So, there are different types of practical that you can do involved in the photosynthesis. But however, the one that we are going to focus on is the starch test. You know the starch.

Learners: Yes.

Researcher: Starch em remember when you were doing uh plant tissues in grade 10 you were taught about Xylem and phloem. You were told that Xylem transport water and mineral salts from their roots to the aerial parts of the plant. Then you were told what, eh the phloem, it transports what? Phloem? Phloem? (pedagogical knowledge)-**cPCK**

Learners: *Inaudible.*

Researcher: It transports food neh. So, phloem transport food (content knowledge)-**pPCK**, the food that was manufactured during what process? (pedagogical knowledge)-**cPCK** Photosynthesis. Now that food will be stored in the form of starch neh, yes. So now the objectives of this lesson you need to list and describe the materials, and the reagents required for starch neh. Then you should be able to know the significance of each step why are we doing this why are we doing that neh. And then you also need to relate the presence of starch in the leaf to the production of um glucose during photosynthesis. Then you also need to be able to observe and document the changes that takes place in the leaf neh. OK, right and then now firstly let's just go through these apparatus or materials neh. Right um, (content knowledge)-**pPCK** so can somebody tell me what is this? (pedagogical knowledge)-**cPCK**

Learner 1: Iodine solution. (learning context)-**ePCK**

Researcher: This is the iodine solution neh (content knowledge)-**pPCK**. Right now, what's the original color of the iodine solution? (pedagogical knowledge)-**cPCK**

Learner 2: Brown. (learning context)-**ePCK**

Researcher: There's someone saying it's brown (pedagogical knowledge)-**ePCK**, what do you think? (pedagogical knowledge)-**cPCK**

Learner 3: Blue (learning context)-**ePCK**

Researcher: Blue (pedagogical knowledge)-**ePCK**, someone is saying it's blue someone someone else? (pedagogical knowledge)-**cPCK**

Learner 2: Red. (learning context)-**ePCK**

Researcher: Red (pedagogical knowledge)-**ePCK**, so the colour of the, its original, this is the original color neh. Its we saying, we normally say it's reddish brown neh. So that's what we normally say, the color of the iodine solution (content knowledge)-**pPCK**. Now what do we use there in solution for? (pedagogical knowledge)-**cPCK**

Learner 2: To test for starch. (learning context)-**ePCK**

Researcher: To test for starch (pedagogical knowledge)-**ePCK** so in other words the iodine solution is the reagent that is used to test for starch. So, if starch is absent the color of the iodine solution will not change it will remain the same. However, when starch is present the color of the iodine solution will change from reddish brown to blue-black. Blue-black (content knowledge)-**pPCK** neh. Alright and then what do we call this? (pedagogical knowledge)-**cPCK**

Learner 4: Fire. (learning context)-**ePCK**

Researcher: Someone is saying fire (pedagogical knowledge)-**ePCK**. Now, now now now this here is the fire neh. But now what do you call the entire thing? (pedagogical knowledge)-**cPCK**

Learner 4: Fire lighter. (learning context)-**ePCK**

Researcher: Someone is saying fire lighter (pedagogical knowledge)-**ePCK**. Scientific name we say it's a Bunsen Bunner neh. Yes. So, it's a Bunsen Bunner neh. OK, so it's a Bunsen, now it's a Bunsen Bunner (content knowledge)-**pPCK** neh. Right And now what is this? (pedagogical knowledge)-**cPCK**

Learner 2: Ai it's a glass beaker.(learning context)-**ePCK**

Researcher: It's a glass beaker (pedagogical knowledge)-**ePCK**. There's there's a glass beaker and then there's a plastic beaker neh. But for this one you will need a glass beaker neh (content knowledge)-**pPCK**.

Learners: Yes.

Researcher: And then girls, this one you must know. What is that? (pedagogical knowledge)-**cPCK**

Learners: Tweezer. (learning context)-**ePCK**

Researcher: It's a tweezer neh (pedagogical knowledge)-**ePCK**. Right. And then what about this one? This one? (pedagogical knowledge)-**cPCK**

Learners: Test tube. (learning context)-**ePCK**

Researcher: We call it a, a test tube neh (pedagogical knowledge)-**ePCK**. So, this is a test tube and then and then what do we call this one? (pedagogical knowledge)-**cPCK**

Learner 2: A holder. (learning context)-**ePCK**

Researcher: It's a test tube holder neh (pedagogical knowledge)-**ePCK** . Yah, so you use it to hold that test tube neh. And then what about this? What's the normal word for ethanol? (pedagogical knowledge)-**cPCK**

Learner 3: Alcohol. (learning context)-**ePCK**

Researcher: Alcohol neh (pedagogical knowledge)-**ePCK**.Yes, but if you don't have an alcohol, you can use a spirit as a substitute because you see this Bunsen Bunner, this one this is the one that uses a gas neh. Then there's a manual one neh whereby you just pour either an alcohol or a spirit or a sanitizer to start the fire neh. Alright. And then I'll try it. Now you have made me think of something. I'll try it and see if it works (content knowledge)-**pPCK**. Yah, and then um what is this? (pedagogical knowledge)-**cPCK**

Learner 5: Three foot. (learning context)-**ePCK**

Researcher: Yah what do we call it? It's a tripod stand neh. It's a tripod stand OK. Right. And then now what about this? (pedagogical knowledge)-**cPCK**

Learner 2: It's a sieve. (learning context)-**ePCK**

Researcher: It's a what? (pedagogical knowledge)-**cPCK**

Learner 2: It's where you put the glass beaker. It's a sieve. (learning context)-**ePCK**

Researcher: Where you put eh…

Learner 2: A glass beaker. (learning context)-**ePCK**

Researcher: A glass beaker (pedagogical knowledge)-**ePCK**, some they call it a gauze neh. And then what about this here? (pedagogical knowledge)-**cPCK**

Learners: It's a leaf. (learning context)-**ePCK**

Researcher: This is a leaf neh (pedagogical knowledge)-**ePCK**. OK and then here? (pedagogical knowledge)-**cPCK**

Learners: Water. (learning context)-**ePCK**

Researcher: Water (pedagogical knowledge)-**ePCK**. And then here? (pedagogical knowledge)-**cPCK**

Learner 6: A host plate. (learning context)-**ePCK**

Researcher: Someone is saying a plate (pedagogical knowledge)-**ePCK**.

Learner 5: Container. (learning context)-**ePCK**

Researcher: Scientific plate.

Learner 2: Container. (learning context)-**ePCK**

Researcher: Container. (pedagogical knowledge)-**ePCK**

Learner 4: Tupperware. (learning context)-**ePCK**

Researcher: Tupperware. (pedagogical knowledge)-**ePCK**

Learner 2: Microscopic plate. (learning context)-**ePCK**

Researcher: We call it a petri, petri dish neh.

Learners: Yes.

Researcher: We call this a petri dish neh. OK, so now uh guys I know that maybe in high school they will give you an exception neh when you don't have uh you see a a a a a lab attire. So, what I know is that um in some institutions if it's a lab day like if you're going to have a practical and you don't have the following, they don't allow you to enter inside the lab neh. Yah, its for safety reasons neh, so, when you enter the lab, you need to have the following especially if youre going to use toxic chemicals. You will need to have what? A lab coat, you will need to have, these are the safety googles neh yes. Then you will need to have gloves cause sometimes when people enter the lab, they use uh toxic substances like acids and you cannot touch an acid without having the protective gloves neh. Right. And then you need to wear clothes, clothes that are covered neh, shoes that are covered yah like your shoes they must be covered. You cannot enter a lab a lab wearing flipflops, or high heels. You need to have flat shoes that cover your toes neh. And then even your clothes they need to cover your body neh. Right. Then you need to have your lab clo…you're your lab coat. If you have long hair you need to tie it nicely neh and neat and clean and all of that it's for safety reasons neh. OK, and then now we move on. I want you to watch this video(SAMR) carefully neh. So so so you see it's an animation. Someone mentioned that animation, thank you. Watch carefully, we gonna play it again. I want you to observe what's going on here. Theres no audio for a reason neh. So, I want you to observe whatever you see here (content knowledge)-**pPCK**. Are you are you guys following what's going on here? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: You need to watch this. Remember you still have your November paper neh.

Learner 2: Yes.

Researcher: So, it's gonna come very handy. OK, let me just go back neh. So so so you see uh this experiment. This experiment it's a test a leaf for starch neh. So, if you don't uh do this experiment to test for the present of starch you can just bring in different types of food. Like your banana, your apple, your onion, your uh your fruits and veggies basically neh. So, you can just uh have small pieces of each and every uh type of food that you bring in. But you can use the iodine solution. Do you remember the iodine solution? You can just put one drop in each and every type of food and observe if there will be any changes neh. Then those changes they will tell you about the presence of starch. If there's a presence of starch, then it tells you that photosynthesis did actually take place in that em plant neh. Right but uh this is another way of uh finding starch neh. So, what we will need to do um. You will have to have your tripod stand neh, you gauze, and you will have to have your beaker. Then you will have to have water, you boil the water neh. And then once the water starts boiling you gonna pick a fresh leaf neh. Yah uh just a fresh leaf, it doesn't have to be eh eh a huge leaf a small one neh. Yah, yes so you see they tell you plug the leaf from the plant which is exposed to sunlight and boil it in water for about five minutes. So, when you boil the leaf what you do to the leaf is that you are making it to be soft neh. Yah cause they are telling you to soften the leaf. Now one of the question that they like asking neh and there's a that um famous question that they like asking, why are you boiling the leaf for five minutes? You must know neh. Right. (content knowledge)-**pPCK**

Learners: Yes

Researcher: So, if you're using the, remember when we spoke about the Bunsen Burner. I showed you the one that uses the gas neh. And I told you there's a manual one where you need to use a sanitizer, alcohol, and spirit neh. That one it normally takes time. So, if you want to move fat you can just use eh eh eh electrical kettle neh. Boil the water then pour the water in the glass beaker and then in that way you are speeding up the process neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: Alright. OK, let's carry on and watch. The …*inaudible*…carries on and says take the leaf out and place it in the petri dish. (content knowledge)-**pPCK** You still remember the petri dish? (pedagogical knowledge)-**cPCK** Someone said it's a Tupperware. Yes, so now you are you are not using you're your fingers to take out that leaf cause remember that leaf its inside the boiling water neh. (content knowledge)-**pPCK** But you are using what? (pedagogical knowledge)-**cPCK** The the tweezer for safety measures neh. Then you see (content knowledge)-**pPCK**, you remember that test tube? (pedagogical knowledge)-**cPCK** You're now going to take that test tube. You're gonna pour the alcohol inside the test tube. (content knowledge)-**pPCK**

Learner 2: What about the spirit? (learning context)-**ePCK**

Researcher: Mmm? (pedagogical knowledge)-**cPCK**

Learner 2: The spirit, does it it have alcohol? (learning context)-**ePCK**

Researcher: Yah, yah I think the spirit does have the alcohol neh. Yes, and then now you take put the leaf into the test tube and pour alcohol. You must make sure that the alcohol it covers the entire leaf neh. Right. Now the same, this same alcohol you're gonna take it back to the, to your boiling water neh. Now, they will ask you something about why are we pouring the alcohol in the test tube neh and take in that test tube and put its inside the beaker with boiling water. Why not take the the the the beaker and put the alcohol (content knowledge)-**pPCK** and put the what's thing this thing? The leaf and let it boil, why? (pedagogical knowledge)-**cPCK**

Learner 7: We want separate things. (learning context)-**ePCK**

Researcher: Why? (pedagogical knowledge)-**cPCK** Someone is saying we want separate things.

Learner 8: Alcohol is flammable. (learning context)-**ePCK**

Researcher: Alcohol is flammable. So, of you boil it directly to the fire you're gonna start fire. So, if you put it inside the water we call it the water bath. In other words, you're stopping any flames from. You're stopping the alcohol from catching any flames. So, you see here this water we call it the water bath cause it's like you're putting the alcohol inside the test tube inside the water in the beaker. So, that makes it a water bath to prevent the alcohol from catching any flames neh. OK, and then now they say a water bath is used to prevent accidents that may arise from the alcohol being inflammable neh. So, now you put off the flame when the alcohol starts boiling neh. This is another way to uh for safety measures. You see now you will observe that the leaf has now become what colorless. So, it's like you are taking away neh you're you're stopping all the activities that are taking place in the cell. Remember uh inside the cell whether it's a plant cell or an animal cell. There's a lot of activities that are taking place. Lot of processes. In a plant cell you know there's uh photosynthesis taking place, there's cellular respiration taking place, there's protein synthesis taking place, there's mitosis taking place and more. You understand, so when you are doing this process, you're stopping all the cell's activities neh. OK, right (content knowledge)-**pPCK** . Now you you the minute you see that the leaf is now colorless you're now going to do what? (pedagogical knowledge)-**cPCK** To remove it neh. OK, so as alcohol warms up it dissolves the chlorophyll(content knowledge)-**pPCK** and leaf turns what? (pedagogical knowledge)-**cPCK** Colorless. Wash the decolourised leaf with warm water to clean it and. So, when you remove that leaf from the alcohol it's hard. So, you need to put it back in this water to make it soft neh. Yes, right. And then now you're gonna uh take your iodine solution then you gonna take a dropper of an iodine solution. You're gonna pour it on top of the leaf (content knowledge)-**pPCK**. When you pour it on top of the leaf you are going to do what? (pedagogical knowledge)-**cPCK** Observe, so, the most important thing that you are going to do here is observe the color change neh. Cause that's the things that will likely ask you most about. The color change uh now how they ask these questions, they ask them in two ways. What conclusion can be drawn from this and what are the results? Those are two different things neh. The results it's what you see neh (content knowledge)-**pPCK**. So so so so is the leaf is the what's this? The iodine solution remaining the same or is it changing color? (pedagogical knowledge)-**cPCK** Those are your results (content knowledge)-**pPCK**. Then conclusion its your you draw you conclusion from what? (pedagogical knowledge)-**cPCK** From results. That's how you draw the conclusion. So, the results will help you come up with a conclusion to say oh since it changed color from this color to that color then it means that photosynthesis did take place or not neh. Right, OK, and then uh you should see you see now when it becomes blue-black you should now that photosynthesis has taken place. You're not looking at the leaf you're looking at the iodine solution that you have poured where? In the leaf. You're looking at whether its gonna change color or not. If it changes color, it needs to move from reddish brown to blue-black. Now that those are the results of the investigation neh (content knowledge)-**pPCK**. Now the the conclusion will be that eh this is an indication that photosynthesis has what? (pedagogical knowledge)-**cPCK**

Learners: Occurred. (learning context)-**ePCK**

Researcher: Has occurred. Right! OK now so that's all. Now this diagram(SAMR) here is just a representation of that video neh. This diagram(SAMR) here is a representation of that video. You know that you see this is a manual Bunsen burner neh. I told you, you can use a spirit, you can use the alcohol, you can use the sanitizer nhe. Yah, then you will start your fire. This is a beaker; you boil the leaf. Then after boiling your leaf what are, you going to do you're gonna remove the leaf you pour in the test tube then you pour the alcohol inside the est tube. You take it back here (content knowledge)-**pPCK**. We call this a water bath. Why? Why are we using a water bath? I said because the alcohol is water? (pedagogical knowledge)-**cPCK**

Learners: It's flammable.(learning context)-**ePCK**

Researcher: It's flammable neh. So, without the water bath you can burn the school neh. Yah and then um when you're done with that, you're going to remove uh that leaf (content knowledge)-**pPCK** . You're gonna pour it where? Back to the water to to do what? To make it what? (pedagogical knowledge)-**cPCK**

Learner 4: Soft. (learning context)-**ePCK**

Researcher: To make it soft neh (pedagogical knowledge)-**ePCK**. Right. And then when you're done, you're now going to move the leaf to what? What do you call this? (pedagogical knowledge)-**cPCK**

Learners: Petri dish. (learning context)-**ePCK**

Researcher: A petri dish neh (pedagogical knowledge)-**ePCK**. Yes, you're gonna move it to a petri dish, petri uh dish neh. Then this is? What color is this here? (pedagogical knowledge)-**cPCK**

Learners: Reddish brown. (learning context)-**ePCK**

Researcher: Reddish brown neh (pedagogical knowledge)-**ePCK**. So, I told you if it's reddish brown it tells you that there's no starch. If there's no starch it means no photosynthesis neh. (content knowledge)-**pPCK** Yes, then if it's, what color is this? (pedagogical knowledge)-**cPCK**

Learners: Blue-black. (learning context)-**ePCK**

Researcher: So, if its blue-black it tells you that starch is present and that's an indication that photosynthesis has taken place. Those are the key things that you need to remember neh. Alright, um Ok. So, can we just quickly go through these questions together as a classroom so we can finish quicker neh (content knowledge)-**pPCK**. Why was the leaf initially put in a beaker of boiling water? (pedagogical knowledge)-**cPCK**

Learner 4: So that the leaf can be dissolved. (learning context)-**ePCK**

Researcher: So, that the leaf can be so soft (pedagogical knowledge)-**ePCK**. Anyone else? (pedagogical knowledge)-**cPCK**

Learner 2: To remove the color of the leaf. (learning context)-**ePCK**

Researcher: To remove the color of the leaf (pedagogical knowledge)-**ePCK**. Anyone else? (pedagogical knowledge)-**cPCK**

Learner 7: To destarch the starch. (learning context)-**ePCK**

Researcher: To destarch it (pedagogical knowledge)-**ePCK**. Anyone else? (pedagogical knowledge)-**cPCK** Yes.

Learner 9: To clean it. (learning context)-**ePCK**

Researcher: To clean it (pedagogical knowledge)-**ePCK**. Anyone else? What's what's happening inside the leaf? (pedagogical knowledge)-**cPCK** Under normal circumstances.

Learners: Photosynthesis. (learning context)-**ePCK**

Researcher: There's what? Photosynthesis. Is it only photosynthesis that's taking place inside the leaf? What other processes are taking place there? There's another there's another…inaudible…neh. So, when you boil it you stop all the activities neh. Now, but when you boil it in the alcohol that's when you're removing what? (pedagogical knowledge)-**cPCK**

Learners: The chlorophyll (learning context)-**ePCK**

Researcher: The chlorophyll neh (pedagogical knowledge)-**ePCK**, yes. Cause when it becomes colourless it means it no longer contains the chlorophyll neh, yes. And then they saying test tube with boiling water, (content knowledge)-**pPCK** why was test tube with boiling water placed inside the glass beaker with the boiling water? I said what? (pedagogical knowledge)-**cPCK**

Learner 2: You said to prevent flames. (learning context)-**ePCK**

Researcher: To prevent? (pedagogical knowledge)-**cPCK**

Learners: Flames. (learning context)-**ePCK**

Researcher: Because the alcohol is what? (pedagogical knowledge)-**cPCK**

Learners: Flammable. (learning context)-**ePCK**

Researcher: Flammable neh (pedagogical knowledge)-**ePCK**. We know that this alcohol here is flammable. So, therefore uh you gonna need the water bath to prevent the alcohol from catching the flames. (content knowledge)-**pPCK** Now which color change is observable when you were watching the video? What color change did you see? (pedagogical knowledge)-**cPCK**

Learner 2: Colourless. (learning context)-**ePCK**

Researcher: Colour change, color change, color change in relation to where you poured the iodine solution. (content knowledge)-**pPCK**

Learners: Blue-black. (learning context)-**ePCK**

Researcher: Blue-black neh (pedagogical knowledge)-**ePCK**. So, you know that eh the leaf change from the the the the iodine solution after it was poured it changed from reddish brown to blue-black neh. Now when they say describe the results that's also where you're going to speak about the color change. When you describe the results, you speak about the color change. Results its what you have seen neh. If I was to come up with the different experiment that lets say it does not involve this uh maybe the hypothesis was eh do (content knowledge)-**pPCK** , we have Jabu here?

Learners: No.

Researcher: OK, what's your name?

Learner 5: Learner 5.

Researcher: Let's say the hypothesis is that if learner 5 was to stand up and jump she would float in the middle of the classroom, that's an hypothesis eh (content knowledge)-**pPCK**.

Learners: Yes.

Researcher: Remember it's a prediction (content knowledge)-**pPCK**. The next step would be to do what? To ask her to do what? To? (pedagogical knowledge)-**cPCK**

Learners: Jump. (learning context)-**ePCK**

Researcher: Now if she jumps for us, I'm gonna observe what's going to happen. If she jumps, what do you think will happen? (pedagogical knowledge)-**cPCK**

Learner 9: She will fall. (learning context)-**ePCK**

Researcher: Someone's saying fall (pedagogical knowledge)-**ePCK**, someone's saying? (pedagogical knowledge)-**cPCK**

Learner 8: Fall. (learning context)-**ePCK**

Researcher: Fall back neh. If I see her fall, those are the results neh. Now the conclusion would be when learner 5 jumped she did not…who's learner 5? Oh, when learner 5 jumped they did not float in the middle of the classroom they were pulled back to the ground by the force of gravity. Eh, you see. (pedagogical knowledge)-**pPCK** I I hope you picked up the difference between results and conclusion cause the problem with these skills neh they you go you go with them to grade 12 neh. And unfortunately, in grade 12 there's no to be for you to be babied neh. It's content content content content neh. Alright, and then do you know how to write the word and the chemical equation for photosynthesis? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Let's write the chemical equation. What must I start with? (pedagogical knowledge)-**cPCK**

Learner 10: Sunlight, sunlight. (learning context)-**ePCK**

Learner 2: Oh, chemical equation? (learning context)-**ePCK**

Researcher: Chemical Equation (pedagogical knowledge)-**ePCK**.

Learner 8: Ohhh.

Learners: CO_2 (learning context)-**ePCK**

Researcher: CO_2 (pedagogical knowledge)-**ePCK**

Learners: Plus, water, plus H_2O. (learning context)-**ePCK**

Researcher: Plus, H_2O (pedagogical knowledge)-**ePCK**.

Learners: Radiant energy. (learning context)-**ePCK**

Researcher: Eh! H_2O plus? (pedagogical knowledge)-**cPCK**

Learner 9: Enzymes. (learning context)-**ePCK**

Researcher: What must must I write enzymes here? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: What must I do? (pedagogical knowledge)-**cPCK**

Learner 9: C4, an arrow. (learning context)-**ePCK**

Researcher: An arrow? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: OK an arrow and then? (pedagogical knowledge)-**cPCK**

Learner 2: Chlorophyll over enzymes. (learning context)-**ePCK**

Researcher: Chlorophyll here? (pedagogical knowledge)-**cPCK**

Learners: Yes. No. Yes. Chlorophyll over enzymes, chlorophyll over enzymes. (learning context)-**ePCK**

Researcher: What? (pedagogical knowledge)-**cPCK**

Learners: Chlorophyll over enzymes. (learning context)-**ePCK**

Learner 2: Not enzymes over chlorophyll. That is totally wrong. (learning context)-**ePCK**

Researcher: And then. Is it? Is that all? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: OK. And then what must I write? (pedagogical knowledge)-**cPCK**

Learners: CO_2, radiant energy. (learning context)-**ePCK**

Researcher: O_2. OK and then is that all? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: OK what must I write? (pedagogical knowledge)-**cPCK**

Learners: C_6 (learning context)-**ePCK**

Researcher: C_6 (pedagogical knowledge)-**ePCK**

Learners: H_{12} (learning context)-**ePCK**

Researcher: H_{12} (pedagogical knowledge)-**ePCK**

Learners: O_6 (learning context)-**ePCK**

Researcher: O_6 neh (pedagogical knowledge)-**ePCK**. Now this is something that you need to write without copying from your book neh. OK uh. Right. Now listen neh. Are we allowed to scream here? (pedagogical knowledge)-**cPCK**

Learners: Yes, no, yes. (learning context)-**ePCK**

Learner 8: Are we allowed to scream? They will make noise.

Learners: Yes, we do want to scream. (learning context)-**ePCK**

Researcher: Can we get the timekeeper. So, we to we need you to open your phone neh. Open your phone. And then here we gonna do two things neh. The first thing that you're gonna do we have about 14 words neh. Those 14 words they cover they cover everything that Ma'am taught you and what I just showed you now neh. So, you are going to …someone is going to be our timekeeper for 30 seconds. When I display the words, you only have 30 seconds to describe what you can about the word neh. Are we clear? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Are you ready? Anyone. You snooze you lose. OK. Are you ready? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: First word here. What can you tell me about this word? (pedagogical knowledge)-**cPCK**

Learner 8: Glucose. (learning context)-**ePCK**

Researcher: Glucose (pedagogical knowledge)-**ePCK**. What else can you tell me about this word? (pedagogical knowledge)-**cPCK**

Learner 8: Iodine solution. (learning context)-**ePCK**

Researcher: This starch? Starch? (pedagogical knowledge)-**cPCK** Make a sentence. Make up something.

Learner 9: Found in the grana. (learning context)-**ePCK**

Researcher: Found in the grana? Is the starch found in the grana? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: Yes.

Learner 10: Stored in the starch grain. (learning context)-**ePCK**

Researcher: Yes, stored in the starch grain neh (pedagogical knowledge)-**ePCK**. What else can you tell me about this? (pedagogical knowledge)-**cPCK**

Learner 4: It's a by-product (learning context)-**ePCK**

Researcher: Do we still have how many…it is? (pedagogical knowledge)-**cPCK**

Learner 4: A by-product. (learning context)-**ePCK**

Researcher: Is it a by-product? (pedagogical knowledge)-**cPCK**

Learners: No. (learning context)-**ePCK**

Learner 8: Time. (learning context)-**ePCK**

Researcher: OK someone said by-product. Can I fix that neh. The starch it's not the by-product neh. It's a product but it's a product when it's a product (content knowledge)-**pPCK** it's still a what? (pedagogical knowledge)-**cPCK** A glucose neh. The by-product of the entire photosynthesis is the oxygen neh. Yah the oxygen it is the one that is the by-product neh. Yah cause it's not kept by the by the plant. The plant will release that oxygen into the atmosphere neh. You're gonna have another word. When I say tell me anything that you can you can tell me whatever. Whether it's a requirement, whether it's a product whether the definition or the description or whatever you can that's relevant its acceptable neh. OK so we need to see if your brain can think under stress or whatever. Alright. Iodine solution (content knowledge)-**pPCK**

Learner 7: Alcohol. (learning context)-**ePCK**

Researcher: Alcohol? (pedagogical knowledge)-**cPCK**

Learners: Color changer, it test for starch. (learning context)-**ePCK**

Researcher: It test for starch neh. OK, yes. Anything else? (pedagogical knowledge)-**cPCK**

Learners: Reddish brown. (learning context)-**ePCK**

Researcher: It is reddish brown neh. The original color neh. OK what else? (pedagogical knowledge)-**cPCK**

Learners: It changes to dark blue. (learning context)-**ePCK**

Researcher: It changes to? (pedagogical knowledge)-**cPCK**

Learners: Blue-black. (learning context)-**ePCK**

Researcher: Blue-black (pedagogical knowledge)-**ePCK** when.

Researcher and the learners: When the starch is present neh.

Learner 8: 5,4,3,2,1 time.

Researcher: You wanted to say.

Learner 11: You use it as a sanitizer. (learning context)-**ePCK**

Researcher: Mm? (pedagogical knowledge)-**cPCK**

Learner 11: You use it as a sanitizer. (learning context)-**ePCK**

Researcher: No no no no no no. Hhayi hhayi. Waisteba *(do you know)* 30 second? They can ask you your name wari wari *(and you say, and you say)*.....

Learner 2: That sanitizer. (learning context)-**ePCK**

Researcher: Hhe he. Guys come on you still have few more words. You still have few more words to get this right neh. Eh are you ready? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: In 3, 2, 1 OK. Glucose.

Learners: ATP, sugar, ATP, sugar, sugar, ATP. (learning context)-**ePCK**

Researcher: ATP? (pedagogical knowledge)-**cPCK** Yah, glucose ATP because glucose is used during cellular respiration. It's broken down to release energy in the form of ATP neh. OK. Glucose. (content knowledge)-**pPCK**

Learners: It's stored as starch. (learning context)-**ePCK**

Researcher: It's stored as class as starch (pedagogical knowledge)-**ePCK**.

Learners: As starch. (learning context)-**ePCK**

Researcher: As starch neh (pedagogical knowledge)-**ePCK**.

Learner 8: End the result of photosynthesis. (learning context)-**ePCK**

Researcher: End the result of photosynthesis (pedagogical knowledge)-**ePCK**.

Learner 2: Sugar sugar, there's a sugar inside. (learning context)-**ePCK**

Researcher: It's known as sugar also neh (pedagogical knowledge)-**ePCK**.

Learners: Yes.

Researcher: Yes. What else can you tell me? (pedagogical knowledge)-**cPCK**

Learners: 4,3,2,1,0.

Learner 9: Carbohydrates. (learning context)-**ePCK**

Researcher: Oh, carbohydrates neh (pedagogical knowledge)-**ePCK**.

Learners: Time.

Researcher: Yah remember when you were doing uh the chemistry of life in grade 10 neh. They did tell you that a glucose it is a monosaccharides or disaccharides? (pedagogical knowledge)-**cPCK**

Learners: Disaccharides. (learning context)-**ePCK**

Researcher: Eh guys come back come back come back. Chlorophyll.

Learners: I's a green pigment. (learning context)-**ePCK**

Researcher: It's a green pigment (pedagogical knowledge)-**ePCK**.

Learner 7: Mitochondrion. (learning context)-**ePCK**

Learners: Huh.

Learners: Found in the chloroplast. (learning context)-**ePCK**

Researcher: Found in the chloroplast neh (pedagogical knowledge)-**ePCK**.

Learners: Sunlight. Traps sunlight. (learning context)-**ePCK**

Researcher: Traps sunlight yes (pedagogical knowledge)-**ePCK**.

Learners: Thylakoid (learning context)-**ePCK**

Learner 2: Grana. (learning context)-**ePCK**

Researcher: Thylakoid. We find it in the thylakoid.

Learner 2: Grana. (learning context)-**ePCK**

Researcher: We find it in the grana (pedagogical knowledge)-**ePCK**. What else? (pedagogical knowledge)-**cPCK**

Learner 2: Uh um light phase light phase. (learning context)-**ePCK**

Learner 3: Chloroplast. (learning context)-**ePCK**

Researcher: It's used in the light phase? (pedagogical knowledge)-**cPCK**

Learner 2: Yes.

Researcher: Is it used in the light phase? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Yes neh. Alright. Found in the leaves right.

Learner 2: Found in the chloroplast. (learning context)-**ePCK**

Learners: 3,2,1.

Researcher: Found in the chloroplast. Ei at least you guys know chlorophyll neh.

Learners: Yes.

Researcher: Yah yah yah it's your thing. Oxygen.

Learner 2: Breath in breath in. (learning context)-**ePCK**

Researcher: You breathe oxygen and breath it out? (pedagogical knowledge)-**cPCK**

Learners: No. Inhalation inhalation. (learning context)-**ePCK**

Researcher: You inhale the oxygen from where? (pedagogical knowledge)-**cPCK**

Learners: Plants. (learning context)-**ePCK**

Researcher: From the atmosphere, from the plants. OK.

Learner 7: It's a by-product of…*inaudible*…(learning context)-**ePCK**

Researcher: It's a by-product of? (pedagogical knowledge)-**cPCK**

Learners: Photosynthesis. (learning context)-**ePCK**

Researcher: Yes, of photosynthesis neh (pedagogical knowledge)-**ePCK**.

Learners: Yes.

Learner 2: If you combine it with eh hydrogen so that you can get water. (learning context)-**ePCK**

Learner 8: Yes.

Researcher: You can combine it with hydrogen to get water ay yes sir yes sir (pedagogical knowledge)-**ePCK**. What else? What else can you say about oxygen? (pedagogical knowledge)-**cPCK**

Researcher and the learners: *Inaudible.*

Learner 8: 4, 3, 2.

Researcher: Yho OK.

Learner 8: Time.

Researcher: But he's not lying.

Learner 2: Yes.

Researcher: He's not lying neh. OK. Now can we move on to another word? (pedagogical knowledge) **pPCK**

Learners: Yes.

Researcher: Right. Phosphorylation, do you know this one? (pedagogical knowledge)-**cPCK**

Learner 14: Iyho! Yho ai.

Learners: ADP, dark phase, dark phase for photolysis. (learning context)-**ePCK**

Researcher: ADP plus plus ADP plus. Guys help him ADP plus? Huh haa. He's right, ADP plus? (pedagogical knowledge)-**cPCK**

Learners: We don't know. (learning context)-**ePCK**

Researcher: To form to form. Let me give you a clue. To form ATP. ADP plus? (pedagogical knowledge)-**cPCK**

Learner 2: Glucose. By-product. (learning context)-**ePCK**

Learner 8: 5,4

Researcher: ADP plus

Learners: Carbon dioxide, Hydrogen (learning context)-**ePCK**

Learners: 3,2,1

Learner 2: Hhayi it's only 10 seconds.

Learner 8: It's 30.

Researcher: OK, guys. ADP he was right neh. ADP stands for adenosine diphosphate with a what? With a phosphate will give you ATP neh. Right(content knowledge)-**pPCK**. Hhuh uyabona? Hai ubaphethe san *(you're doing well* (pedagogical knowledge)-**pPCK***)*. Can we move on? (pedagogical knowledge)-**pPCK***)*.

Learners: Yes.

Researcher: Are you ready? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Alright. Eh timer. Haibo uyabona *(see)* Chloroplast.

Learner 7: It's where photosynthesis takes place. (learning context)-**ePCK**

Researcher: It's where photosynthesis takes place (pedagogical knowledge)-**ePCK**.

Learner 14: Has a grana inside it. (learning context)-**ePCK**

Researcher: Has a grana inside it (pedagogical knowledge)-**ePCK**.

Learner 7: It is found in the leaf. (learning context)-**ePCK**

Learner 14: Thylakoid. (learning context)-**ePCK**

Researcher: Found in the leaf which is correct.

Learner 2: Has a chlorophyll. (learning context)-**ePCK**

Researcher: Has a chlorophyll inside. Yes. (pedagogical knowledge)-**ePCK**

Learner 15: Has two different membranes. (learning context)-**ePCK**

Researcher: Has two different membranes which are inner membrane (pedagogical knowledge)-**ePCK** and the? (pedagogical knowledge)-**cPCK**

Learners: Outer membrane. (learning context)-**ePCK**

Learner 7: Has two phases which is the light phase and the dark phase. (learning context)-**ePCK**

Researcher: Maybe you can say it's…

Learner 8: Time.

Researcher: It's a site

Learner 2: Hhayi wayirobha loyi. Wayirobha loyi. *(this one is cheating us, this one is cheating us).*

Learner 7: Uyayizwa mara le 30 second? *(do you feel this 30 second?)*

Researcher: Right. You're correct neh. Chloroplast it's also a site for photosynthesis neh when you look at the organelles neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: Right. Can we move on? (pedagogical knowledge)-**pPCK**).

Learners: Yes.

Researcher: OK. Are you ready? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: OK. Don't worry ehh you now have few few words to shine. Let's see you shine.

Learners: Sun. (learning context)-**ePCK**

Researcher: Sun. What else? (pedagogical knowledge)-**cPCK**

Learners: Energy supplier. (learning context)-**ePCK**

Researcher: Energy supplier (pedagogical knowledge)-**ePCK**.

Learners: Light phase. Chlorophyll. (learning context)-**ePCK**

Researcher: Light phase (pedagogical knowledge)-**ePCK**.

Learner 2: Trapped by chlorophyll. (learning context)-**ePCK**

Researcher: It's used in the light phase. Yes.

Learner 2: Trapped by chlorophyll. (learning context)-**ePCK**

Researcher: Trapped by chlorophyll to do what? (pedagogical knowledge)-**cPCK**

Learner 4: To produce. (learning context)-**ePCK**

Learner 10: It's a raw material for photosynthesis. (learning context)-**ePCK**

Researcher: It's a raw material for photosynthesis.

Learner 10: Can't happen without it. (learning context)-**ePCK**

Researcher: Photosynthesis cannot happen without it. Someone is being smart. Yes. Yes. Anything else? (pedagogical knowledge)-**cPCK**

Learner 3: Sanitizer. (learning context)-**ePCK**

Researcher: Sanitizer? Bathong? Yho! Oh OK.

Learner 10: You're not you're not participating.

Learner 15: Mina, I'm a timekeeper, I'm not supposed to participate.

Learner 10: You must participate.

Researcher: You are listening? (pedagogical knowledge)-**cPCK**

Learner 15: I am listening hau.

Researcher: Photolysis.

Learner 2: The split of water. (learning context)-**ePCK**

Learner 9: It splits, it splits water. (learning context)-**ePCK**

Researcher: The splitting of? (pedagogical knowledge)-**cPCK**

Researcher and the learners: Water into hydrogen and oxygen neh.

Researcher: What else can you say about this? (pedagogical knowledge)-**cPCK**

Learner 10: Light phase. (learning context)-**ePCK**

Researcher: What splits the water? (pedagogical knowledge)-**cPCK**

Learner 7: Uh takes place in the chloroplast. (learning context)-**ePCK**

Learner 10: In the grana. (learning context)-**ePCK**

Researcher: Takes place in the chloroplast, takes place in the grana (pedagogical knowledge)-**ePCK**. Yes.

Learners: *Inaudible.*

Learner 8: 4,3,2,1

Researcher: Photolysis, we know photolysis is the splitting of water molecule into hydrogen and oxygen neh. OK. Um carbon dioxide. (content knowledge)-**pPCK** Someone does…

Learners: *Inaudible.*

Researcher: It's what? (pedagogical knowledge)-**cPCK**

Learner 2: You breath it out. (learning context)-**ePCK**

Learner 3: Its toxic for humans. (learning context)-**ePCK**

Learner 7: It's a requirement(learning context)-**ePCK**

Researcher: OK. Humans they breathe it out because its toxic for them neh.

Learner 7: Requirement of photosynthesis. (learning context)-**ePCK**

Researcher: Requirement for photosynthesis (pedagogical knowledge)-**ePCK**.

Learners: *Inaudible.*

Researcher: The the trees they? (pedagogical knowledge)-**cPCK**

Learner 2: They absorb (learning context)-**ePCK**

Researcher: They absorb the carbon dioxide neh (pedagogical knowledge)-**ePCK**. Through what? (pedagogical knowledge)-**cPCK**

Learner 1: Through the stomata. (learning context)-**ePCK**

Researcher: Through the stomata (pedagogical knowledge)-**ePCK** and what do you find around the stomata? What opens what opens and closes the stomata? (pedagogical knowledge)-**cPCK**

Learners: Guard cells. (learning context)-**ePCK**

Researcher: Guard cells neh (pedagogical knowledge)-**ePCK**.

Learners: Yes.

Researcher: Yes. OK. Blue-black.

Learner 2: Color of iodine solution. (learning context)-**ePCK**

Learners: Iodine solution. (learning context)-**ePCK**

Learner 2: When starch is present. (learning context)-**ePCK**

Researcher: Color of iodine solution when starch is present neh (pedagogical knowledge)-**ePCK**.

Learners: Yes.

Researcher: What does this tell you when its blue-black? (pedagogical knowledge)-**cPCK**

Learners: That photosynthesis took place. (learning context)-**ePCK**

Researcher: That photosynthesis has taken place neh (pedagogical knowledge)-**ePCK**. OK. So, can we move on here? (pedagogical knowledge)-**pPCK** Right. Stroma.

Learner 2: Its where dark phase takes place. (learning context)-**ePCK**

Researcher: This is where the dark phase takes place neh (pedagogical knowledge)-**ePCK**. What else? Strom is where the dark phase takes place neh. You can say it's a site for dark phase neh. If you don't wanna say dark phase, what do you say? (pedagogical knowledge)-**cPCK**

Learners: Light-independent phase. (learning context)-**ePCK**

Researcher: Light-independent phase (pedagogical knowledge)-**ePCK**. These. Uh guys listen neh. These are some of the eh eh few things that they can just throw in the multiple choice neh or in the biological terms neh.

Learner 2: Ma'am eh it's the site for dark phase. (learning context)-**ePCK**

Researcher: Or the A only. Mmm?

Learner 2: It's a site for dark phase. (learning context)-**ePCK**

Researcher: Yes, it's a site for dark phase (pedagogical knowledge)-**ePCK**. Reddish brown.

Learner 2: It's the color of…*inaudible*…(learning context)-**ePCK**

Learner 1: Color of the iodine solution. (learning context)-**ePCK**

Researcher: It's the color of the iodine solution neh (pedagogical knowledge)-**ePCK**. Yes. So, if the if you pour the iodine solution in the leaf and it doesn't change its color it means starch is not? (pedagogical knowledge)-**cPCK**

Researcher and the learners: Present neh.

Researcher: OK. Stomata.

Learner 1: Transport theee…(learning context)-**ePCK**

Learner 2: It allows thee…. its its (learning context)-**ePCK**

Learner 10: Easy diffusion. (learning context)-**ePCK**

Learners: Huh!

Researcher: Guys the stomata.

Learner 6: It happens when it's when its dark. (learning context)-**ePCK**

Researcher: Huh?!

Learner 2: Allows the the the movement (learning context)-**ePCK**

Researcher: The movement of? (pedagogical knowledge)-**cPCK**

Learner 2: Gas. (learning context)-**ePCK**

Researcher: The movement of gases neh (pedagogical knowledge)-**ePCK**. Yes. Cause you remember carbon dioxide and oxygen are gases. So, it allows the movement of gases. It allows the carbon dioxide to enter and the oxygen to exit neh. (content knowledge)-**pPCK**

Learners: Yes.

Researcher: Alright. And we know that in the stomata we find cells. Those cells we call them the guard cells neh. And we know also transpiration (content knowledge)-**pPCK** Do you still remember transpiration? (pedagogical knowledge)-**cPCK** Water loss in the form of water vapor in the stomata. Don't learn to forget neh. Grana. (content knowledge)-**pPCK**

Learner 2: Grana is light phase. (learning context)-**ePCK**

Learner 1: It has chlorophyll. (learning context)-**ePCK**

Learner 2: Light phase. (learning context)-**ePCK**

Researcher: Huh?

Learner 16: Separates. (learning context)-**ePCK**

Learner 1: It has chlorophyll. (learning context)-**ePCK**

Researcher: It has chlorophyll (pedagogical knowledge)-**ePCK**. OK. What else? (pedagogical knowledge)-**cPCK**

Learner 16: Separation of oxygen and hydrogen. (learning context)-**ePCK**

Learner 2: *Inaudible.*

Researcher: Thylakoids.

Learner 2: Yah thylakoids. (learning context)-**ePCK**

Researcher: Yah yah stacks of thylakoids (pedagogical knowledge)-**ePCK** they form a grana neh. This is where the light phase takes place neh. OK. Yah the stacks. Yah the thylakoids they form the grana neh (content knowledge)-**pPCK**. OK. Our time is up. Right. Now listen neh. Let me first save here and then I want use to do something quick quick then then we are done. OK. Um, now listen neh. So, so so let me just do this. So, I need you guys to sit in groups of five neh. Groups of five.

Learner: Groups? (learning context)-**ePCK**

Researcher: Yes. Five groups quickly.

Learner 2: Let's make them rows.

Researcher: Yho 1 2 3 4 5 neh. Right. Now, haibo. So, I'm waiting for this to load. What time is it now? (pedagogical knowledge)-**cPCK**

Learners: 2.

Researcher: 2. We have 15 minutes neh…*inaudible…*

Zandaya: Ende beyivelile ngalesa skhathi neh. *(and it appeared that time).*

Researcher: Yah.

Zandaya: Kanti wenzani lapho. Heh! Nizohlangana nezinye izinto. *(what are you doing there? You will see things you are not supposed to see).*

Learners: *Inaudible* (*learners chatting while the teacher was busy logging on to her emails on the smartboard*).

Researcher: Uh listen. Can you take out your phone neh. I need you to scan something for me neh. So, this group here, how many are you here? (pedagogical knowledge)-**cPCK** So, this group you're answering that question neh. The first one. So, you scan here you're gonna answer the first question neh. So, let scan and then you gonna answer the first question neh. Eh guys please get your phones ready to scan neh. I'm coming….*inaudible…*

Zandaya: Woh ayiveli lah? *(its not appearing here)*

Researcher: Ayiveli. Angazi why. Melivele. *(it's not showing, I don't know why. Its supposed to show)* Please scan, scanner nge phone *(scan with a phone)*. Um wait I'm giving you more questions neh…*inaudible*…I'll give you your question. You're not scanning the same question neh…*inaudible* … yes. Alright and you guys I want you to scan this neh…*inaudible*…scan this. And then you're answering neh. You have your own question neh.

Learner 2: Eh Ma'am sicel favor. *(Ma'am please do us a favor).*

Zandaya: Ama response wenu why angabonakali *(why are your responses not showing?)* cause they supposed to show here. Ama answer akumelanga aphume ebhodini*?.(are the answers not supposed to appear in the smartboard?)...inaudible...*cause they supposed to show here. No, this shows this one.

Researcher: Yazin. Ngicela ume lapho. *(you know what, you know what, please stand there)*

Zandaya: Ayifuni siloge in? Yiwo lawa *(it doesn't want us to log in? those are the ones)*

Researcher: Yah yah yah.

Zandaya: So, these are your answers neh.

Learner 8: Oh.

Zandaya: But it does not show.

Researcher: It does not show who answered neh

Learner 8: I see mine I see mine I see mine. (learning context)-**ePCK**

Learners: *Inaudible.*

Zandaya: Yho iphone ka Ma'aam. Kaze nifuna ukubonani…*inaudible…(a teachers phone, I wonder what is it that you want to see)*

Researcher: OK. Guys its fine. Can I just quickly go through your responses. I want to see something. Someone says it's a process by which chlorophyll in the chloroplast of green plants absorbs radiant energy from the sun carbon dioxide from the atmosphere and water from the soil to produce carbohydrate. Can I ask? Is there anything wrong with this? (pedagogical knowledge)-**cPCK** Photosynthesis is the process by which the chlorophyll in the chloroplast. Eh guys listen. If this is your response don't take any offense neh. Photosynthesis is the process by which the chlorophyll in the chloroplast of the green plant absorbs radiant energy from the sun (content knowledge)-**pPCK**. So, does it absorbs carbon dioxide? (pedagogical knowledge)-**cPCK**

Learners: No.

Researcher: So, you see what's wrong with this definition neh. We have to remove carbon dioxide neh from the atmosphere and water from the soil neh (content knowledge)-**pPCK**.So, we can say photosynthesis is the process by which chlorophyll in the plant in the chloroplast of green plants absorbs radiant energy to produce carbohydrate. (learning context)-**ePCK** We can take that one neh. So, our challenge it's where? (pedagogical knowledge)-**cPCK** It's from the sun neh. Yah so so you cannot say eh absorbs radiant energy from the sun then you say comma carbon dioxide. So, in other words you are telling us that carbon dioxide has the radiant energy neh. OK. Let me see. Show all responses. Photosynthesis is the process by which plants use sunlight, water, and carbon dioxide to create their own food in the form of glucose, releasing oxygen as a by-product (content knowledge)-**pPCK**. Can we accept this definition? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Definitely. Neh. It is the process by which chlorophyll in the chloroplast of green plants absorbs radiant energy from the sun, carbon dioxide, atmosphere. I've already spoken about this neh. OK. Process by which radiant energy is converted to chemical potential energy, stored in organic compound produced from carbon dioxide and water (content knowledge)-**pPCK**. Can you accept this? (pedagogical knowledge)-**cPCK**

Learners: Yes.

Researcher: Photosynthesis. Remember we said according to your own understanding neh. Photosynthesis is the process by which plants use sunlight, water, and carbon dioxide to create their own food in the form of glucose, releasing oxygen as a by-product. Can you accept this one (content knowledge)-**pPCK**.

Learners: Yes.

Researcher: OK. I see something about organic. Ziphi ezenu *(where are yours?)*. Ok, its gonna need us to load. Photosynthesis is an organic process where green plants absorb sunlight (radiant enrrgy) using chlorophyll, water and carbon dioxide in order to make its by-product oxygen and glucose. It's correct but the English is not englishing neh. Yah is the process by which plants manufacture their own food in the presence of radiant energy, water to produce oxygen and glucose in a form of starch (content knowledge)-**pPCK**. Can we accept this one? (pedagogical knowledge)-**cPCK** No neh.

Learner 16: Eyiphi leyo Ma'am? Enagthi eyami nje. *(Which one is that one? It looks like mine)* (learning context)-**ePCK**

Researcher: Hau kanti why uziveza? *(why are you disclosing yourself?)*

Learner 16: Kanti asivezwa? *(so, we are not supposed to disclose ourselves?)* (learning context)-**ePCK**

Researcher: It's a process by which plants manufacture their own food in the presence of radiant energy. OK I think I touched this. Yiyo le *(this is the one)* neh. Eh water to produce oxygen and glucose in a form of starch. No no, you can say glucose is stored neh. You can say glucose in the form of. Glucose is stored in a form of starch neh. Yah, so, I think that's it for today neh (content knowledge)-**pPCK**. Thak you guys.

APPENDIX 14: Semi-structured Interview Questions

<u>Semi-Structured Interview Questions for all three participating schools</u>

Prior the collective lesson planning process:

The following questions were asked to each teacher from each of the three schools respectively:

1. How frequently do you use a smartboard and why?
2. What smartboard features do you prefer the most and why?
3. Can you describe your overall instructional approach to teaching photosynthesis using the smartboard? How does this smartboard support your pedagogical goals?
4. Based on your experience as a life sciences grade 11 teacher, what challenges and misconceptions do learners have when it comes to photosynthesis topic and how do you use a smartboard to confront the challenges and the misconceptions that learners have when it comes to photosynthesis?
5. Can you describe how you use the smartboard to facilitate learner collaboration during photosynthesis lessons?

After the first lesson:

The following questions were asked to each teacher from each of the three schools respectively:

School 1

1. Based on the lesson you just delivered, describe the specific features of the smartboard that were the most beneficial in facilitating the learners understanding of photosynthesis?
2. Were there any specific teaching strategies that seemed particularly effective in combination with the use of the smartboard based on the lesson you just delivered?
3. The quiz given to the learners gave them immediate feedback in terms of what they got correct and incorrect. How else can you use the smartboard to give the learners immediate feedback and please describe the type of feedback that the learners will receive and why?
4. Based on your observations, how engaged were the learners during the lesson? What factors contributed to their engagement or disengagement?

5. While utilizing the smartboard for corrections, you engaged a learner to annotate the responses directly over the questions displayed in the PowerPoint presentation. Could you elaborate on the pedagogical rationale behind this decision? Given that you could have performed this task yourself, what benefits did you anticipate from involving the learner in this process?

School 2

1. Based on the lesson you just delivered, describe the specific features of the smartboard that were the most beneficial in facilitating the learners understanding of photosynthesis?
2. Were there any specific teaching strategies that seemed particularly effective in combination with the use of the smartboard based on the lesson you just delivered?
3. The quiz given to the learners gave them immediate feedback in terms of what they got correct and incorrect. How else can you use the smartboard to give the learners immediate feedback and please describe the type of feedback that the learners will receive and why?
4. Based on your observations, how engaged were the learners during the lesson? What factors contributed to their engagement or disengagement?
5. While your nails may have posed a challenge during your recent use of the smartboard, resulting in limited annotation, how might you adapt your approach to ensure optimal utilization of this technology without compromising nail length?
6. How can the effectiveness of smartboards be enhanced to stimulate greater learner engagement and interaction during the lesson, given that some the learners participation was passive?

School 3

1. Based on the lesson you just delivered, describe the specific features of the smartboard that were the most beneficial in facilitating the learners understanding of photosynthesis?
2. Were there any specific teaching strategies that seemed particularly effective in combination with the use of the smartboard based on the lesson you just delivered?
3. The quiz given to the learners gave them immediate feedback in terms of what they got correct and incorrect. How else can you use the smartboard to give the learners immediate feedback and please describe the type of feedback that the learners will receive and why?

4. Based on your observations, how engaged were the learners during the lesson? What factors contributed to their engagement or disengagement?

After the second lesson: Feedback session

School 1

1. How did the teacher use the smartboard to create a more interactive and engaging learning environment?
2. Did the teacher effectively use the smartboard to differentiate instruction and cater to the diverse learning needs of the learners?
3. How did the teacher use the smartboard to provide immediate feedback on learner's assessments and to facilitate remediation?
4. How did the teacher effectively integrate the Smartboard into the lesson? Were there any instances where the technology could have been used more strategically to enhance learning?
5. What role did the PowerPoint presentation play in supporting the teacher's explanations and visual aids? Were there any areas where the presentation could have been improved or enhanced?

School 2

1. How did the teacher use the smartboard to create a more interactive and engaging learning environment?
2. Did the teacher effectively use the smartboard to differentiate instruction and cater to the diverse learning needs of the learners?
3. How did the teacher use the smartboard to provide immediate feedback on learner's assessments and to facilitate remediation?
4. How did the teacher effectively integrate the Smartboard into the lesson? Were there any instances where the smartboard could have been used more strategically to enhance learning?
5. What role did the PowerPoint presentation play in supporting the teacher's explanations and visual aids? Were there any areas where the presentation could have been improved or enhanced?

School 3

1. How did the teacher use the smartboard to create a more interactive and engaging learning environment?

2. Did the teacher effectively use the smartboard to differentiate instruction and cater to the diverse learning needs of the learners?
3. How did the teacher use the smartboard to provide immediate feedback on learner's assessments and to facilitate remediation?
4. How did the teacher effectively integrate the Smartboard into the lesson? Were there any instances where the technology could have been used more strategically to enhance learning?
5. What role did the PowerPoint presentation play in supporting the teacher's explanations and visual aids? Were there any areas where the presentation could have been improved or enhanced?
6. How effective was Mentimeter in assessing learners' understanding of photosynthesis after the lesson? Can you suggest other ways to use Mentimeter with a smartboard in a Grade 11 classroom to enhance the teaching of photosynthesis?
7. Given the potential of smartboards to enhance interactive learning, would you recommend Mentimeter as a tool to support the teaching of photosynthesis in a Grade 11 classroom?

APPENDIX 15: Semi-structured Interview Transcripts: School 1 before collective lesson planning process.

School 1 before collective lesson planning process

Researcher: Um, So how frequently do you use a smartboard and why?

Jade: Um, I I actually do not use a smartboard frequently, uh due to issues of sometimes electricity, issues of um malfunctions of the smartboard at times, but when I do use that, it is to make the lesson more effective. It is to to show my learners more content rather than just them looking at or hearing what I'm saying. So ,it's to show them something, eh! And the reason why I I use it more is because I've noticed that Learner's become more engaged when they see visuals, which helps in making the experience more interactively. (pedagogical knowledge)-**pPCK**

Researcher: Okay. And then what smartboard features do you prefer the most and why?

Jade: Um I'm not sure really of the features per say. Yes I'm not sure of the features, uh but I only use the features that allowed me to write so there's um not sure if it's a software that is called IQ interactive. IQ interactive allows me to write to draw uh even change colours, highlight where I need to highlight(SAMR). So, that helps in explaining complex concepts, uh when I'm teaching. So, it thee these features that I'm talking about make it easy to illustrate processes and diagram(SAMR) uh dynamically (pedagogical knowledge)-**pPCK**

Researcher: Um Okay. So, can you describe your overall instructional approach to teaching photosynthesis using the smartboard? How does this technology support your pedagogical goals?

Jade: Okay, um usually when I start a topic, I will start with an engaging photo(SAMR) or image(SAMR) is the proper word, I think, or diagram K where I will project that picture(SAMR) of green plants and then ask learners what do they know about photosynthesis, what comes into mind when they see pictures(SAMR) like this. So, this visual often um stimulates or help learners um it helps capture learners' attention. It also provides a clear overview of the whole processes that I'm about to talk about. But sometimes I use as smartboard to display and annotate diagrams(SAMR) of photosynthesis, um and when we are annotating(SAMR), it's often an interactive lesson. So it means I'm interactive with the diagrams(SAMR) with the learners and at that also I am able to highlight(SAMR) different stages of photosynthesis. I am able to explain all their components or all the requirements of photosynthesis by looking at the diagrams(SAMR) (pedagogical knowledge)-**pPCK**

Researcher: Okay Ma'am. And then based on…

Jade: Yes.

Researcher: On your experience as a life sciences grade 11 teacher, what challenges and misconceptions do learners have when it comes to photosynthesis topic and how do you intend to use a smartboard to confront the challenges and the misconceptions that learners have?

Jade: Based on?

Researcher: Based on your experience as a life sciences grade 11 teacher, what challenges and misconceptions do learners have when it comes to photosynthesis topic and how do you intend to use smartboard to confront the challenges and the misconceptions that learners have when it comes to photosynthesis?

Jade: Okay, it is the importance of chlorophyll and chloroplast. There is often a confusing about the role of chlorophyll, as well as the function of chloroplast in the photosynthesis process. And then the other misconception or confusion is between photosynthesis and cellular respiration. So, when I'm explaining the equation of photosynthesis, some learners link it with cellular respiration equation, which is um yeah, that that creates a bit of con misconception, because in grade eight, they are taught about cellular res they are thought about respiration rather. And then uh when they get to grade 11, I'm trying by all means to to remove those misconceptions that they have of cellular respiration and photosynthesis being the same topic. Okay. So, to address this misconceptions, I often use…*inaudible*…So, I will display display a side by side comparisons of photosynthesis, as well as of cellular respiration on the smartboard, so it will help uh clarify the differences as well as the connections which reinforces the unique role or in energy transformation. Okay, so it shows learner's visual diagram(SAMR) of chlorophyll, as well as visual diagrams(SAMR) with the chloroplast, and to explains how they all differ. K, that is all (content knowledge)-**pPCK**

Researcher: Okay, and then can you describe how you use the smartboard to facilitate learner colla…

Jade: Learner?

Researcher: Can you describe how you use the smartboard to facilitate the collaboration during photosynthesis lesson? Can you describe how you use the smartboard to facilitate learner collaboration during photosynthesis lessons?

Jade: I often use quizzes. You know this game gamified. I don't know what are called. There's a simulation software that I often use. There are quizzes from, for example, Kahoot. I use polls there and there, but I hardly use polls to force that discussion amongst the learners. So, the learners are then able to use the smartboard to brainstorm and also visualize their ideas connected them. That's all.

Researcher: Okay.

APPENDIX 16: Semi-structured Interview Transcripts: School 1 after lesson 1.

Researcher: Based on the, based on the lesson which just delivered, described the specific features of the smartboard that were most beneficial in facilitating the learner's understanding of photosynthesis.

Jade: I think I used more of the presentation um plus presenting a lot of pictures as well as annotation(SAMR) affordance (pedagogical knowledge)-**pPCK**

Researcher: Okay.

Jade: So, I believe those were…cause that way, there is diagram(SAMR) of chloroplast that I annotate(SAMR), there is a diagram(SAMR) of a chloroplast that I'm displaying, that I'm presenting to the learners. Yes (pedagogical knowledge)-**pPCK**

Researcher: Okay. Where there any specific teaching strategies that seemed uh particularly effective in combination with the use of the smartboard based on the lesson you've just delivered?

Jade: Uh, yes, online simulations often work best for me, or it worked first, not that it often it worked works just after the lesson, and the educational games that we often that we play, um the 30 seconds, I think it worked perfectly. The quiz that we also played using google forms. I think it worked better things of this uh interactive smartboard. Yes. (pedagogical knowledge)-**pPCK**

Researcher: Okay. And then now um, the quiz given to the learners gave them immediate feedback in terms of what they got correct and what they got incorrect. How else can you use the smartboard to give them an immediate feedback and please describe the type of the feedback that the learners will receive and why?

Jade: Okay, so the problem there is that I do not have internet connectivity. My learners do not have cell phones or gadgets that they can use, but if I did have phone connectivity, then I would use Kahoot more more frequently, same as the virtual, uh virtual field trips, as well as either interactive whiteboard apps that are available. But due to the constraint of internet activity, as well as um the fact that we are marginalized in terms of uh having technology, then I can't really use any other thing, except for kahoot, because with kahoot, at least I'm quiet to have about five phones and that will mean five groups. And I often need to connect the learners to the internet so that they are able to do that. So yes, there are um uh uh ways of giving learner immediate feedback, but it's it's impossible with the circumstances I am faced with (assessment knowledge)-**pPCK**

Researcher: Okay, okay. And then based on your observations, how engaged were the learners during the lesson? What factors contributed to the engagement or the disengagement?

Jade: So, most learners were fully engaged really. Uh only a few that do not like talking in class were sort of bored for lot of the period. However, about 90% of the class was actively learning and disengaging could have been caused by their personalities. So, for example, learners that are quiet in general, as well as learners that are active, that will learn that doing that I can kinaesthetic. So, um if their learning style is not a movement, talking, then I can't force them to interact fully. So, they get disengaged. Yes (pedagogical knowledge)-**pPCK**

Researcher: Okay, thank you.

APPENDIX 17: Semi-structured Interview Transcripts: School 1 after lesson 2, Feedback session.

Researcher: How did I use the smartboard to create a more interactive and engaging learning environment?

Jade: Okay, you used presentation affordance to engage the leaners so to to bring their minds to completion, um if I may say, you used the presentation affordance, um and then you also used annotation to add all the information that there was uh not on the presentation already, uh to add all the the information again, that was being mentioned by the learners. So, this simultaneously allowed you to use the writing and the erasing function. And then you also used, uh I think we played a game, so gamified affordance, if there's an affordance like that, there allows you to um to use uh I don't know, to engage with learners interactively while playing games in a way. (pedagogical knowledge)-**pPCK**

Researcher: Okay. So, did did I effectively use the smartboard to differentiate instruction and cater to the diverse uh learning needs of the learners?

Jade: Yes I believe you. There was a video(SAMR), so the video to me was catering to auditory learners. It was also at the same time catering for uh visual learners. There were diagrams(SAMR) that you had display, there was catering to visual learners. Um and then you could have also used uh the interactive simulations, I think due to time that um also catered to the kinaesthetic learners because then with a simulation they are able to go and add to remove and and and put the, I don't know, label the chloroplast for example, the way should be labelled using the labels that are there. So yes, you did use um the smartboard…*inaudible*. (pedagogical knowledge)-**pPCK**

Researcher: Okay, so how did…

Jade: Yes.

Researcher: I use the Smartboard to provide immediate feedback on learners' assessment and to facilitate remediation?

Jade: Yah the multiple questions in the quiz they showed, and they gave learners immediate feedback. So, um what are they called the google form or google link?

Researcher: Not not not um not the one that you taught like based on the one, the lesson that I was teaching, you know.

Jade: Yes.

Researcher: Yah cause the the the activities that I gave the learners with that class work on the smartboard and then it was that um interactive 30 seconds with one word on the smartboard.

Jade: But uh you are breaking the angithi you used a quiz, which was a google form.

Researcher: The quiz was for… Um, how did the teacher use the smartboard to provide immediate feedback on learner's assessments and to facilitate remediation?

Jade: Okay, so the teacher or Researcher used the classwork. There was the classwork the she gave the learners where she had displayed questions on the smartboard and then asked the learners to come and answer. So, the learners would come and annotate on the board or write on the smartboard, (SAMR)use the erasing function as well, and then should come and tick that this is correct and then they discuss whether what what do the other answers that were possible. And then secondly, uh Researcher displayed would play a 30 seconds game, so an academic 30 seconds, where she would display biological term on the board and then from there learners were expected to describe what they are seeing. While that description was happening, the the smartboard was also timing the 30 seconds for the learners, so a a smartboard function that was also used there was the stopwatch. There, yes. (pedagogical knowledge)-**pPCK**

Researcher: So, so the the words that you say…

Jade: So…*inaudible*… was short and it gives learners immediate feedback.

Researcher: Okay. So those those words that were displayed were they displayed using word document, what was used?

Jade: Sorry.

Researcher: Tho tho those um words that were displayed, were they displayed using a word document or what?

Jade: Uh they were used the displayed using a presentation, what what is it called? PowerPoint presentation. (pedagogical knowledge)-**pPCK**

Researcher: Okay, okay. And then…

Jade: Cause I think we had you you Researcher was busy editing them they saw it was a PowerPoint presentation. (pedagogical knowledge)-**pPCK**

Researcher: Okay. And then how did the teacher effectively integrate the smartboard into the lesson? Where there any instances where the smartboard could have been used more strategical to enhance learners like you felt like okay I felt like this is what I I could have done more like the eee like based on the observations that you had?

Jade: Okay, wait, where are we now?

Researcher: I'm saying like, how did the teacher? How did I effective integrate the smartboard into the lesson? Where there any instances where you felt like I could have used the smartboard in in a very more strategical way?

Jade: Exactly, because the affordances the affordances that she used uh were the ones that were available on the smartboard. Um maybe if we had internet connectivity we would have um facilitated the visuals maybe visual search chips where learners could look at um at something that is outside the field trip while they're inside the classroom. Well, but no, I don't think the were other strategies that she could have used um maybe just to assess learner's um label diagrams(SAMR). We could have used a drag and drop off an image(SAMR). So for example, the structure of a chloroplast to you you ask them to fully drag and drop all the the organelles that are found in the chloroplast, as well as labels that should be in the, but I believe those all that are these were not used due to the time cost uh constraint, as well as the limited information of how to actually use them. Um so yes, I think the Researcher is also yet to to learn about how to fully use the smartboard. (pedagogical knowledge)-**pPCK**

Researcher: Okay. And on what role did the PowerPoint presentation play in supporting the teacher's explanations and visuals visual aid, were there any areas where the presentation could have been improved or enhanced?

Jade: Presentation showed learners what they need to see what they need to visualize, and also a guide to the teacher on what they need to mention and um, yes, the movement of the flow of the lesson. So, they also guide the the teacher in that manner. So no, this is one instance I believe, um it catered for all of our learners. Everything that they could visualize, everything they could visualize as it was well presented in a presentation format. So, if something I believe that you overcompensated um for all the other learning aids that were there. You were able to um uh cater for our visual learners like I said, for our kinaesthetic as well as for our auditory learners. So, yah I believe the visual aids did support your explanations in the PowerPoint presentation. They also the videos(SAMR) that you were using, they were also a part of the PowerPoint presentation. (pedagogical knowledge)-**pPCK**

Researcher: Okay. Is there anything else that you would like to say or ask me or recommendations for future use of the smartboard?

Jade: All right, maybe what I would suggest uh you Researcher, I notice that you sort of finished a smartboard in isolation, so you used the writing presentation, the uh annotation (SAMR)function in isolation. So maybe allow the learners to collaborate more using the smartboard again so let them collaborate on a deeper level, where they are allowed to have their own devices. So, these devices would also also add better when you you are are including the learning management system in there such as your google classroom, because with the google classroom, you'll be able to track learners' activities to check their progress. Learners are writing activities, and if they are doing um uh uh their work even without you being there in class. So, there's a a a smartboard software. I'm going to say call it a software that is installed in these smartboards right now. um So it helps the teacher, if the learner is using their tablets, they are the teacher will be able to check what activity are they doing, how faster are they doing it so maybe also if you have enough time to to integrate the affordance of the smartboard, then uh uh integrate Google classrooms in there so that there is more collaboration there there is more real time feedback for your learners. But otherwise, I believe you did your best for the person who's never used the smartboard, so yeah, well done, Ma'am (pedagogical knowledge)-**pPCK**

Researcher: Thank you, Ma'am that will be all.

APPENDIX 18: Semi-structured Interview Transcripts: School 2 before collective lesson planning process.

Researcher: So how frequently do you use a smartboard in the classroom and why

Samantha: Okay so um is this directly directed to great 11s only?

Researcher: No like in general yes.

Samantha: So, um in my school, there's different classes. Some classes have smartboard, some classes do not have smartboards and (learning context)**-pPCK** so I mostly use a smartboard in my grade 11 and grade 12 classes because the content number one in grade 11 and grade 12 it is more abstract, and a smartboard makes it easier for them to be able to see what we are talking about and to be able to understand that. And then also other than that um the grade 10 classes do not have smartboards. So only the grade 11 and the grade 12 classes have smartboards (pedagogical knowledge)**-pPCK**

Researcher: Okay, so meaning that for your grade 11s you mostly use the smartboard for teaching?

Samantha: Yes

Researcher: okay and then um what smartboard features do you do you prefer to use and why?

Jade: I prefer to use a power presentation because one I'm able to edit it from home and get to use it in class and then also it allows me to be able to annotate(SAMR) on the smartboard um whilst teaching which then helps me to be able to apply the same um changes to another class which I will be teaching the same topic. So, it allows for continuation of lessons and improvement of lessons (pedagogical knowledge)**-pPCK**

Researcher: Okay, okay. All right. So can you describe…

Samantha: Ngicel ubambe kancane *(please hold on)*…. I am back

Researcher: So, can you describe your overall instructional approach to teaching photosynthesis like um using smartboard and how does this technology this smartboard support your pedological goals?

Samantha: So, um with teaching with the smartboard, especially with photosynthesis it has topics that learners are familiar with, but then they don't get to know it in depth as it is in great 11 content. So, it makes it easier for me to teach the topic because it enables you to show the chloroplast at the larger scale and to be able to show all the other parts that I found in the chloroplast on on a larger scale in the smartboard. And then which allows me to be able to explain the different phases, the light phase and the light phase using the smartboard (pedagogical knowledge)-**pPCK**

Researcher: So, like, based on your experiences as a life sciences grade 11 teacher, what challenges and misconceptions do learners have when it comes to photosynthesis topic and how do you intend or rather say, how do you use a smartboard to confront the challenges and the misconceptions that learners have when it comes to photosynthesis.

Samantha: So, as I have, okay, wooow, are you recording this?

Researcher: yes

Samantha: Oh, okay okay. um so as I have mentioned that photosynthesis is the topic that learners are familiar with, but then they don't know it in depth. So, they have, of course there is this new concept, um the light phase and the dark phase it's only introduced in grade 11. So, the learners have a difficulty differentiating the phases. Therefore, when using a smartboard, I can simply just show the different parts of the chloroplast which allows me to be able to explain which one is responsible for the light phase and which one is a responsible for the dark phase, and it also shows that the products of the light phase are used in the dark phase. So that's how it helps (pedagogical knowledge)-**pPCK**

Researcher: Okay. And then can you describe how you use the smartboard to facilitate learner collaboration when you teach photosynthesis like during the photosynthesis lessons.

Samantha: Okay so normally at the end of a topic, I would use a crossword puzzle on the smartboard so that will increase their understanding of the technology used photosynthesis in the topic and then also um it will also be able to help them knowing the spelling of different terms in photosynthesis. Then also, I also give like the structure of the whole chloroplast whereby the learners are supposed to come and label on the smartboard or the labels and the functions of the different parts of the chloroplast (assessment knowledge)-**pPCK**

Researcher: Okay, um Thank you.

APPENDIX 19: Semi-structured Interview Transcripts: School 2 after lesson 1.

Researcher: OK, so um based on the lesson you just delivered can you describe the specific features of the smartboard that were the most beneficial in in terms of facilitating the learners understanding of photosynthesis.

Samantha: So, because we were using, I was using PowerPoint and the ability to be able to annotate (SAMR)on the board to make it easier for the learners to easily understand the notes that are presented on the smartboard whether rather than just to read what's written on the notes or on the slides to them. So, me being able to write on the board makes it easier for them to understand what we are talking about (pedagogical knowledge)-**pPCK**

Researcher: So, the feature um of the smartboard that you think it's mostly benefits benefiting the learners is the annotation part.

Samantha: Yes

Researcher: Okay. So, where the any specific teaching strategies that seemed particularly effective in combination with the use of the smartboard, based on the lesson just delivered.

Samantha: So, um in the beginning of the lesson, um I started with a show and tell where I showed the learners a picture(SAMR) of trees and then they had to um describe what they are seeing there and in which which concept are the linking that picture to life sciences. So, this makes them to be able to gain interest into the topic and to bring their concentration into what they are going to learn about on the day (pedagogical knowledge)-**pPCK**

Researcher: Okay, so um during the I think um some of the lesson you gave the learners a quiz neh, so the quiz given to the learners gave them immediate feedback in terms of what they got correct and what they did not get correct. How else can you use the smartboard to give learner's immediate feedback and please describe the type of feedback that the learners will receive and why?

Samantha: So well, I can simply just upload past question papers on the smartboard rather than to print them out and then this will make it easy for the learners to be able to um for me to be able to assess their understanding with their past papers and then after the learners write, then they after that can just do marking and then this will help them to see how they are supposed to answer their questions about photosynthesis. and then also I could also use the smartboard to display the memo (assessment knowledge)-**pPCK**

Researcher: oh, so you use the feedback would be you displaying the memo on the smartboard?

Samantha: yes

Researcher: okay so um based on your observations, your lesson, how engaged were the learners during the lesson and what factors do you think contributed to their engagement or disengagement?

Samantha: So, the learners we engaged because um I feel like most of the learners are visual learners so them being able to see the organelle in the smartboard it and not just something that I'm trying to explain with my mouth, or it is being an abstract concept. they were able to uh were able to understand eh what the topic is about and what we are focusing on, rather than to just see notes that are black and white on a textbook (pedagogical knowledge)-**pPCK**

Researcher: Okay. And then while um your nails have posed a challenge, you know, when you are writing, they were giving you problems because um they are quite long name, and this result resulted in the limitation use of of annotation. So how will you adapt your approach to ensure minimum utilization of this technology without compromising your length in nails like without like having to just cut your nails?

Samantha: Um well, there's two options. It's either I could get the pen on a smartboard, or I could just simply use a pencil with a rubber eraser at the back. So, because of the rubber it's able to write on the smartboard (pedagogical knowledge)-**pPCK**

Researcher: oh, so the rubber is, the rubber, which is an eraser, is actually sensitive to a smartboard.

Samantha: yes yes it will make it easier for me to annotate rather than just change mine…the length.

Researcher: okay no that’s yho that's yho that's cool. And then how can the effectiveness of smartboard be enhanced to stimulate greater, like greater greater learner, engagement and interaction during the lesson, given that some of the learners their participation was passive.

Samantha: was what?

Researcher: like passive, they would not like actively engaged to were just saying maybe yes because other learners are saying yes.

Samantha: So, um I could just implement resources that promotes active participation because um the attention to span for our learners it is very small (pedagogical knowledge)-**pPCK**

Researcher: mm true

Samantha: So, if I could incorporate games here and there just to keep them excited about the topic, it would make it easier for them to be able to participate at more actively uh (pedagogical knowledge)-**pPCK**

Researcher: I hear you're saying games. Can you maybe give me an example of a game that can just for such learners?

Samantha: uh, there is, we could do as I said, a crossword puzzle where there's two teams. um then there's also I what is it? charades we can do charades where they have to draw structure on the it's not charades oh my God what's the other one I forgot the name where they have to like draw a structure on the board and then their team is supposed to win um tell them what are they drawing on the board then they get points with that (assessment knowledge)-**pPCK**

Researcher: Okay. And then yes carry on.

Samantha: yeah and then also charades where um one team member holds their name of the concept, and the other members are supposed to tell them um the name of the concept. then how I'm using the smartboard to that is to set a timer for the learners to guess the name within the given time interval (assessment knowledge)-**pPCK**

Researcher: oh, okay, so with the the puzzle, it means learners would actually have to go to the smartboard to complete the puzzle.

Samantha: yes

Researcher: Okay, okay, Understood Thank you.

APPENDIX 20: Semi-structured Interview Transcripts: School 2 after lesson 2, Feedback session.

Researcher: OK so as I was teaching neh the second lesson so I'm gonna call myself teacher teacher teacher neh so how did the teacher use the smartboard to create a more interactive and engagement learning environment since we know that for learners to be able to understand they need to be engaged.

Samantha: So, um the teacher taught photosynthesis's experiment using a smartboard. So, she compiled slides, we get pictures, that the learners could see the different apparatus needed for the experiment since obviously my school did not have a lab, so that made it uh more interactive for theology to be able to see. Also, she was able to teach um the rules of being inside of the lab by showing a picture (SAMR)of someone who was wearing appropriate clothes for being inside of the lab (pedagogical knowledge)-**pPCK**

Researcher: So, you are saying that the teacher created an interactive engaging learning environment through the use of pictures?

Samantha: yes

Researcher: eh videos where there any videos? um

Samantha: uh there were vid.., there was a video(SAMR). um so as I've said that since my school does not have a lab, she also taught the experiment to test for starch. she used a video(SAMR) to show the learners how to test for starch so that is also how it became more interactive for the learners to be see how the experiment to test for that is made (pedagogical knowledge)-**pPCK**

Researcher: Okay. So, at the end of this lesson the teacher played a game with a game with the learners 30 seconds neh, where she displayed words and learners had to randomly describe the words. What do you think of that?

Samantha: I think it was a good way to ensure that the learners uh to test for the learner's understanding firstly and also it was a more active way rather than to just ask them um questions about what do they understand what do they not understand? Because sometimes learners are just going to shy around and just call out answers because they hear other learners calling out answers. um not because of what they understand. So, it was a more of an interactive way for the learners to be able to for the teacher also to be able to see if they not understood (assessment knowledge)-**pPCK**

Researcher: Okay. So according to what you have observed, do you think that the teacher like did the teacher effectively use the smartboard to differentiate instruction and cater for the diverse learning needs of the learners.

Samantha: Could you please repeat the question.

Researcher: Did the teacher effectively use the smartboard to differentiate instructions and cater to the diverse learning needs of the learners? So, like do you think the teacher was able to cater to different learning styles?

Samantha: Yes, I believe so because she did not just display notes on the board and kept reading the notes on the board, but she had pictures she had diagrams(SAMR). She had uh also mini here and there and a video(SAMR), which helped her to be able to explain the concept in better (pedagogical knowledge)-**pPCK**

Researcher: Okay. So how did the teacher use the smartboard to provide immediate feedback on learner's assessments and to facilitate remediation?

Samantha: So, she gave the learners an activity on the board and then she also gave them enough time to be able to write the board not the board oh my bad to be able to write the answers um then after that they had she did correction on the board while they were doing corrections. She also re-emphasized on some concepts and then another one she had a link QR code um that was displayed on the smartboard so that learners could fill in um questions based in the concept that she taught (assessment knowledge)-**pPCK**

Researcher: So, when you say the teacher was what exactly it that the teacher was doing on that smartboard that helped the learner to get a immediate immediate feedback?

Samantha: she displayed the answers on the board.

Researcher: So, she just displayed the answers no um writing or annotation or t?

Samantha: Oh, there was there was annotation(SAMR). So, before if I'm not mistaken before the answers were displayed the the teacher was would um discuss the answers with the learners and annotate on the board and then displayed the answers. (assessment knowledge)-**pPCK**

Researcher: So, she first discussed the learners' answers with the learners while annotating on the smartboard then after she was done discussing all the questions with the learners, she now displayed a proper memorandum for learners to copy their answers just in case they missed something?

Samantha: Uh huh, yes exactly that.

Researcher: Okay and then now how did the teacher effectively in integrate a smartboard into a lesson like were there any instances where you feel like the smartboard could have been used the more strategically to enhance learning?

Samantha: Um I don't think the were other ways that you could use it more strategically because she was able to incorporate um the smartboard into a lesson more effectively um also when she used a video(SAMR) she did not just allow the person who was speaking in the video to take over the lesson but then she was the one who was facilitating everything and explaining what was happening in the video (pedagogical knowledge)-**pPCK**

Researcher: So, are you saying that the video was mute? It has no audio.

Samantha: Yes it was a muted video(SAMR) yes.

Researcher: Okay. And then um um you did you mention that that the lesson was a PowerPoint, right?

Samantha: yes it was a PowerPoint

Researcher: So, what role did a PowerPoint presentation play in supporting the teacher's explanations and visual aids visual aids where the any areas where you feel like the PowerPoint itself could have been improved or enhanced?

Samantha: the PowerPoint played a very crucial role in visualizing the experiment rather than to just read as I said that since our learners have a very small attention span, if you could just read notes on the board they wouldn't have captured or understand what you're saying. So, um since the teacher used the PowerPoint to visualize the experiment so that they the learners could see what she was teaching about it made it more effective and then also the presentation was was was it was a good presentation. I don't think there was anything that could be added to enhanced powerful presentation. (pedagogical knowledge)-**pPCK**

Researcher: So, what exactly makes you think that it was a good PowerPoint presentation?

Samantha: because one the notes were visible for the learners to see and it was summarized um concept and also there were pictures(SAMR) there and it allowed her to be able to also annotate(SAMR) on the board did not just write everything everything on the board for the learners to read, but then she was able to add more points on the board for the learners throughout the the lesson. (pedagogical knowledge)-**pPCK**

Researcher: Okay uh Ma'am.

Samantha: also, the pictures were clear the pictures were clear the size of the pictures was also big enough um the video also the pace of the video(SAMR) was not too fast. It was just a video(SAMR) that was allowed her to be able to explain as it played through (pedagogical knowledge)-**pPCK**

Researcher: So, did the teacher like play the video like one time or was there any back and forth back and forth?

Samantha: there was, they were paused there was times where she would pause the video (SAMR)and then explain what is happening in that instant, then allowed for it to play for some time and then explain again as it she at the video(SAMR) came to points where she needed to re-emphasize. (pedagogical knowledge)-**pPCK**

Researcher: Okay. No thank you ma'am. Thank you so much.

APPENDIX 21: Semi-structured Interview Transcripts: School 3 before collective lesson planning process.

Researcher: Good morning ma'am

Zandaya: Good morning. How are you Ma'am?

Researcher: I'm good thank you. I'm so I'm just gonna ask you like a about five questions before you start with your lesson okay, so question number one how frequently do you use as smartboard and why?

Zandaya: Um, I don't use it very frequently because um maybe I can say uh in a week maybe two times reason being is it that we have like external factors, sometimes maybe I will get into class there's no electricity. So, I think uh the main factor not using uh smartboard more frequently it's due to those things. So, we at our school to struggle with electricity at the times. Yeah, but if if there is electricity, I make sure that I use smart smartboards. (pedagogical knowledge)-**pPCK**

Researcher: Okay, and then yeah, you are saying that if there's electricity, you make sure that you use smartboards. So, what smartboard features do you prefer the most and why?

Zandaya: mmm, sorry, sorry I was about to sneeze. Um you said what what smartboards do I use?

Researcher: like you mentioned that you you you use smartboard more frequently when there is electricity so I'm asking neh when you're using that smartboard, what features inside the smartboard do you prefer to use the most and why? Because yah okay.

Zandaya: I'm I'm not sure of the name of it, but uh there's there's a there's this one where you annotate where you write(SAMR). Like probably when I teach then I annotate there. (pedagogical knowledge)-**pPCK**

Researcher: you annotate are saying you use your PowerPoint presentation where you annotate?

Zandaya: yes definitely I use my PowerPoint presentation then maybe I annotate if um I'm explaining something that. (pedagogical knowledge)-**pPCK**

Researcher: What about the smart notebook where you write with your finger or the pen?

Zandaya: well with that I don't use it frequently at all yah cause the thing that I use the more often it's the PowerPoint presentation where I can annotate the other one mmm not really. (pedagogical knowledge)-**pPCK**

Researcher: And then can you describe your overall instruction approach to teaching photosynthesis using the smartboard? How does this smartboard support your pedagogical goals?

Zandaya: uh well, for me, I think it's actually good because I've noticed that uh learners become interactive when I use um the smartboard because when I taught I was photosynthesis, I was able to display uh like pictures(SAMR) for for example, my first lesson I just displayed the pictures of green plants on the smartboard so I've noticed that learners were were interactive uh they were able to to see on the smartboard what was displayed and learners were able to answer the questions that I asked. So, I think um that smartboards are very very effective because it also helps learners who are who can learn differently, who can learn visually. Unlike me coming to class and just be verbal. So, I think they are more more effective. (pedagogical knowledge)-**pPCK**

Researcher: So, you are saying that your overall instructional approach is using diagrams and pictures, just to?

Zandaya: Yes I use diagrams(SAMR) yes I use illustrations such as diagrams(SAMR) I use that. (pedagogical knowledge)-**pPCK**

Researcher: Okay

Zandaya: *inaudible*…I display pictures(SAMR) on the board. I even play videos(SAMR) on the smartboard, while playing the video I explain here and there. (pedagogical knowledge)-**pPCK**

Researcher: So, do your videos have sound or do not have sound or it depends on the type of learners you have?

Zandaya: No, they do have sound.

Researcher: And then now based on your experience as a life sciences grade 11 teacher, what challenges and misconceptions do learners have when it comes to photosynthesis topic and how do you use the smartboard to confront those challenges and those misconceptions that learners' may have when it comes to photosynthesis?

Zandaya: uh Okay, what I've noticed uh regarding the misconception is that in the role of chlorophyll and chloroplast. So, learners uh they usually eh mistaken the chlorophyll and the chloroplast they do not they do not know the difference between. So, there's often confusion about the role of chlorophyll and the functions of chloroplast in photosynthesis. So, another misconception is the confusion between the photosynthesis and cellular respiration. So, learners sometimes confuse photosynthesis with cellular respiration. So, what I usually do to address this mis misconception when using uh the smartboard, I use the visual comparison that display that this that is that would be displayed on the smartboard side by side. So, to show that comparison of photosynthesis and cellular respiration. So, I think this helps to clarify their differences in connection with forcing the uniqueness in in in photosynthesis. So, I think showing the learners visual diagrams(SAMR) of chlorophyll and the chloroplast, learners are able to see the difference in terms of the structure, and also the functions. Also, with eh photosynthesis and cellular respiration when I displayed the diagrams(SAMR), for example, I displayed the the chloroplast to explain photosynthesis then I display the the mitochondria to explain cellular respiration. So I think doing that's when they will remember more. (pedagogical knowledge)-**pPCK**

Researcher: Okay,

Zandaya: So, I think that helps.

Researcher: Alright alright, and then can you describe how you use the smartboard to facilitate learner collaboration during the photosynthesis lessons?

Zandaya: how do I do what?

Researcher: how do you use the smartboard to facilitate learner collaboration like how to make sure that learners are able to work with each other when you teach photosynthesis using the smartboard?.

Zandaya: So, what I do um? I come up with um activities, right?

Researcher: uh mm

Zandaya: So maybe, for example, um I I create a worksheet. I make a work for the learners where they can use a barcode. So probably the learners can scan that and learners I think it become more interactive in the lesson. So also, when I display whatever worksheet that um I displayed on the smartboard, I ask learners, then learners become more interactive and that's all I group them displaying uh any question on the board to work in groups (assessment knowledge)-**pPCK**

Researcher: Okay um that'll be all now and then we'll have our next session after your first lesson, okay? Thank you.

APPENDIX 22: Semi-structured Interview Transcripts: School 3 after lesson 1.

Researcher: OK Ma'am so the question I'm gonna ask you now are based on the lesson that you just delivered to the learners. So, the first question is based on the lesson you just delivered describe the specific features of smartboard that were most beneficial in facili in facilitating the learners understanding of photosynthesis.

Zandaya: Mmm sorry I couldn't hear you please repeat again.

Researcher: Based on the lesson that you were just teaching learners now describe the specific features of smartboard that were the most beneficial in facilitating learner's understanding of Photosynthesis.

Zandaya: Oh, so the interactive features of the smartboard that I used, um I used a PowerPoint presentation. So, that one, um it visually displayed um the the lesson of photosynthesis. So, I was into uh to display the structure of the chloroplast and also I annotated(SAMR) there when we we labelled the structure the chloroplast with the learners. So, I think it has beneficial to learners because learners were able to to become interactive within the lesson. (pedagogical knowledge)-**pPCK**

Researcher: So, you are saying that um the most interactive uh feature that you used to facilitate learners understanding was the use of annotation?

Zandaya: Sorry.

Researcher: Are you saying that the most um specific feature that was beneficial was annotations?

Zandaya: Yes. Definitely cause I annotated (SAMR)on on the PowerPoint presentation. (pedagogical knowledge)-**pPCK**

Researcher: You annotated throughout the lesson? Okay.

Zandaya: Yes.

Researcher: Okay. And then is there anything else you can think of?

Zandaya: Also, I…

Researcher: Like okay.

Zandaya: I used diagrams(SAMR). Is it part of it? (pedagogical knowledge)-**pPCK**

Researcher: Umm.

Zandaya: I also used diagrams(SAMR) to illustrate the process of photosynthesis. (pedagogical knowledge)-**pPCK**

Researcher: Okay, okay.

Zandaya: Is it part of it:

Researcher: Um um, not really, but I think the annotation part it is part of it where you drag, you you erase, you know, your circle, all of that. And then now the next question is, where there any specific teaching strategies that seemed particularly effective, in combination with the use of a smartboard? Like you know that as a teacher, if you take the smartboard apart, there is teaching strategies that we use, so where there any that eh the the they seemed effective when you were are using them together with the smartboard?

Zandaya: Um, I use the interactive quizzes with the learner.

Researcher: Um mm.

Zandaya: It was displayed also on the smartboard. So, yes learners were able to scan the barcode that had quizzes. They able to to answer those questions. (assessment knowledge)-**pPCK**

Researcher: Okay, was this quiz done singular or was it done in pairs? Were learners working a group?

Zandaya: No at first it it was done singular the first activity. Then the the second one, I grouped the learners to work together. (assessment knowledge)-**pPCK**

Researcher: So that did the activities were not the same so that's to why you decided to Okay.

Zandaya: the first one individual, the second one in groups.

Researcher: Okay. Why did you group them in the second one and not the first one?

Zandaya: So, I think uh the reason for that at first uh I've noticed that most of the learners were…not most, but some were struggling.

Researcher: Um mmm.

Zandaya: So, for me, grouping them together, I will help him those ones who were in who were struggling. (pedagogical knowledge)-**pPCK**

Researcher: So, you were pairing them so they can be comfortable with working with their own peers.

Zandaya: Yes yes a lot of them. And also, to learn some of the things with their peers. (pedagogical knowledge)-**pPCK**

Researcher: Okay, okay. And then the quiz given to the learners cause you spoke about that quiz, right? The quiz given to the learners gave them immediate feedback in terms of what they got correct and incorrect. How else can you use the smartboard to give learners immediate feedback and please describe the type of the feedback that the learners would receive and why? (assessment knowledge)-**pPCK**

Zandaya: Please repeat the question again.

Researcher: The quiz given to the learners, it gave them the immediate feedback, like immediately after they were done answering the questions, they got a feedback that here wrong, here right, here wrong, here right, and then how else could you use this smartboard to give learners an immediate feedback so and please describe the type of the feedback that the learners will receive and why, because they the one that they receive on the quiz if I would describe it, I would say it was just letting that letting the learners know what they got wrong and what they got right. And it didn't even show the correct answers. So, what type of feedback? (assessment knowledge)-**pPCK**

Zandaya: Um the only that I used. The only thing that I used that um gave learners immediate feedback it was quizzes. (assessment knowledge)-**pPCK**

Researcher: Yes, that's what you used angithi for the lesson.

Zandaya: Yes.

Researcher: It it was quiz. It gave them immediate an immediate feedback, and the feedback that it gave them was just showing them what they got wrong and what they got right. So, I'm asking ukuthi *(that)* um how else can you use the smartboard to give the learners immediate feedback besides that?

Zandaya: Um I think what I can do what I give, sorry.

Researcher: There can be something you can do vele. Something you can do that maybe you haven't done yah yah.

Zandaya: So, okay. So, what you really do eh after the lesson I make sure that there's there's an activity that learners have to do. So, I just display those questions for probably two minutes. Then after we read to read as class. (assessment knowledge)-**pPCK**

Researcher: So, when you do it together, do you annotate there, or do you just speak? Like how do you do it? And remember, the question is based on the smartboard helping you to give learners immediate feedback, like will the feedback be immediate feedback or will you um maybe they give you the responses and then you mark and then you display them in the smartboard, how would you do it differently?

Zandaya: Oh, I think. Well, I think I'm not sure if I'm correct to your question.

Researcher: Yah.

Zandaya: So, le let's say I display those questions on the smartboard, right? (pedagogical knowledge)-**pPCK**

Researcher: Yes.

Zandaya: Then I ask learners what is photosynthesis.

Researcher: Yes.

Zandaya: The learners would say the answer say I would go back and annotate. Probably I I would go back to the previous slide where I emphasis learners probably had misconceptions. (assessment knowledge)-**pPCK**

Researcher: Oh, so you would link the feedback back to the content, back to the notes that you gave them. Like it's like you would the feedback would be you, re-explaining the content using uh whatever slides that's in the PowerPoint presentation.

Zandaya: Yes Ma'am.

Researcher: Okay, so the next question, based on your observations, ne on your observations while you are teaching, how engaged were the learners during that lesson, and what do you think contributed to their engagement or their disengagement?

Zandaya: So, learners, to be honest, were fully engaged in the lesson. (pedagogical knowledge)-**pPCK**

Researcher: Um hm. And what makes you think they were engaged?

Zandaya: Because when I asked learners, the learners were interactive. Learners could answer questions that were asked, and learners would interact with the smartboard while I was teaching at that time.

Researcher: Why do you think there was so interactive they were so asking questions, they were so giving opinions like what makes you think they were like that?

Zandaya: I think uh the smartboard played a huge role. Because I said sometimes when I teach in class like, I just talk verbally without any diagrams(SAMR) learners are I I I think they become sometimes confused. Maybe they become lost. But whenever I use this smartboard, playing videos(SAMR) annotating learners become more and more interactive. (pedagogical knowledge)-**pPCK**

Researcher: So, you are saying that they prefer a uh visual aids more compared to text, like a written text?

Zandaya: Yes. because uh learners, learners bored when you just read, and you know.

Researcher: Okay okay okay okay. Um. Okay Ma'am that will be all. We'll have our last session after I teach the last lesson.

APPENDIX 23: Semi-structured Interview Transcript: School 3 after lesson 2: Feedback session.

Researcher: Um, Okay, ma'am, so the question is I'm going to ask you now they are based on the lesson that I was just teaching so for context I'll be referring to myself as the teacher. So ,the first question is how did the teacher use the smartboard to create a more interactive and engaging learning environment ? like how did I em create a more interactive and engaging learning environment using a smartboard?

Zandaya: Uh, okay so on my observation um, the teacher created an interactive environment by displaying questions on the smartboard. That was the activity. So, what I've observed in that uh learners were encouraged to respond at that the time and then the second activity she introduced key terminologies. Uh learners were given like 30 seconds to respond uh for example, the learners were given a term by the teacher em chlorophyll. So, so each learner they shared what they knew. So, I think uh this approach was very good because it prompted act active participation. Learners were fully engaged in the lesson and um they were interested uh and motivated as well. So, learners were able to engage with the material that were given by the teacher. (pedagogical knowledge)-**pPCK**

Researcher: Okay, Ma'am. So based on the observations, right, did the teacher effectively use the smartboard to differentiate instructions and cater to diverse learning needs of the learners.

Zandaya: Yes. Definitely. The teacher effectively used to the smartboard to cater different learning styles of the learners. For example, like visual aids we used, and interactive activities were used as well, like your polls, questions that were given to learners. So, for example, some students eh, benefited from those visual presentations, while others were able to engage eh with interactively with the teacher. (pedagogical knowledge)-**pPCK**

Researcher: Can you give me an example of the visual representation uh that the teacher used?

Zandaya: So, uh the teacher used the experiment that was done visually. Reason being um the school doesn't have um the labs. So, the teacher had improvised by using the uh video(SAMR) on the smartboard em that displayed uh the experiment of a test for starch. So, yes that was the visual that was used by the teacher. And in that experiment everything was explained. (pedagogical knowledge)-**pPCK**

Researcher: So, you are saying in another way that actually the smartboard played a huge role in…

Zandaya: Definitely.

Researcher: In in in in um helping since there's no labs in the school to teach the learners.

Zandaya: Yes. Definitely. Even the learners who learn better visually they benefited more.

Researcher: Okay, um how did the teacher use the smartboard to prevail to provide immediate feedback of on learner's assessments and facilitate remediation? I mean where they were wrong, how did she use feedback?

Zandaya: So, at first on the first activity, the the questions were displayed on the smartboard, right. (assessment knowledge)-**pPCK**

Researcher: Um hm.

Zandaya: So, at that time uh, when, okay, the teacher asked the questions, then the teacher allowed the learners to respond. So, eh when when learners responded, the teacher was able to give the feedback, whether the the answers were or the answers were right.

Researcher: Um. So, when you saying the the teacher was giving the feedback, how was this feedback given? Was it given verbally? Was the teacher writing? If the teacher was writing, where was the teacher writing? What was the teacher writing? Was she writing her own thoughts? Was she writing the learner's thoughts? Eh please describe how that played out.

Zandaya: Okay. So, firstly yes um the feedback was giv was given verbally and also as learners were given answers, the teacher was able to respond back to the answers,. Then also the teacher was uh able to annotate on the board from the questions given by the teacher…(pedagogical knowledge)-**pPCK**

Researcher: When you say on the board you mean the smartboard, or you mean the whiteboard or the chalkboard?

Zandaya: Yes. The smartboard. The teacher annotated(SAMR) there. (pedagogical knowledge)-**pPCK**

Researcher: So, by annotating, do you mean the teacher was writing the the learner's feedback on the smartboard?

Zandaya: Yes. The teacher did that.

Researcher: OK and then mm how did the teacher effectively integrate the smartboard in the lesson? Where there any instances where you felt like the smartboard could have been used more strategically to enhance learning? Like is there anything else that you think could have been attempted that eh the teacher could have tried? Eh maybe eh in future, the teacher can do such a thing (pedagogical knowledge)-**pPCK**

Zandaya: Uh I think the lesson was was really effective based on the smartboard.

Researcher: How so?

Zandaya: Um I can't think of thing that maybe it can be negative or something, but uh the the questions eh experiment was seen visually on the smartboard. The teacher could annotate there (pedagogical knowledge)-**pPCK**

Researcher: Okay.

Zandaya: I'm also thinking what could be done better.

Researcher: Yes. For future.

Zandaya: I can't so I can't say that they teacher probably could have used uh the hands on experiment, right? Cause it was the activities was was based on only.

Researcher: On the smartboard. Okay how how about I rephrase it neh. In future if you were to use the smartboard again with the learners, what else could do besides annotation? Is there anything else that you would want to do like like aeh yes, yes yes. Is there anything else that you would try?

Zandaya: Playing a video(SAMR). (pedagogical knowledge)-**pPCK**

Researcher: Yes. Is there anything that you would like to try?

Zandaya: Playing a video(SAMR) but the teacher did that as well. The teacher demonstrated the video of the experiment on the board. Then then the teacher explained while pausing. Explained eh so hence I'm saying that I think the teacher done justice. The the lesson was really effective. (pedagogical knowledge)-**pPCK**

Researcher: Do you possibly think that maybe there's something that we are not aware of that can be done that whereby learners can be um hands on but still it's it's its visual, like not not necessarily visual, but it it's it's it's live, like it's um I'm thinking here, maybe things like virtual laboratory where learners are able to manipulate variables, anything like that.

Zandaya: Okay okay.

Researcher: Um but please do tell me if you feel like there is something, um, that the teachers can do in future that can be eh helping and making the learners to be even more engaged in learning relating to the use of smartboard when teaching it can be any topic. Okay, and then yeah, if you think of anything, even if it's not now, please let me know. And then…

Zandaya: Okay I will definitely do.

Researcher: Yes. And then um what role did the PowerPoint presentation play in supporting the teacher's explanations and visual aids? Were there any areas, whether the presentation could have been improved or enhanced like you feel like maybe this PowerPoint if we have designed it in this way or in that way, it could have been better if we have added, maybe animations or it would have been better, is there anything you can think of now?

Zandaya: So, so, ma'am to be quite honest your lesson was very interactive.

Researcher: Like transition. Ma'am?

Zandaya: Yes. Hence I'm , hence I'm saying that to be quite honest, your your lesson was very, very nice interactive. So, all the…

Researcher: The PowerPoint presentation?

Zandaya: Yes. I don't wanna lie. I can't think of anything that probably could be added because I feel like the lesson my kids had for different learning styles for learners. (pedagogical knowledge)-**pPCK**

Researcher: Um hm.

Zandaya: So, the the role that the PowerPoint that you did it was very very valuable because it uh the teacher reenforced explanations with images(SAMR) that were shown. The diagrams(SAMR) shown as well and also uh the teacher did not include too much information. (pedagogical knowledge)-**pPCK**

Researcher: Um hm.

Zandaya: On the board. The teacher was able to explain further so hence I'm saying that the for me the lesson was quite quite interesting and meaningful to learners. (pedagogical knowledge)-**pPCK**

Researcher: Okay, Ma'am. So, how eh so during the the lesson there was what the teacher implemented um not implemented but it is what a teacher used. The mentimeter, so the teacher logged in into a email address, clicked to the link for mentimeter, and that process. So how effective was the mentimeter in assessing learner's understanding of photosynthesis after the lesson? Can you suggest other ways to use uh mentimeter with smartboard in a grade 11 classroom to enhance the teaching of photosynthesis?

Zandaya: Uh okay, so firstly the uh the mentimeter eh proved effectiveness in assessing understanding through anonymous polling that was done and also quizzes after the lesson. So, this allowed uh learners to express their comprehension without any pressure from the teacher. So, other uses could include brainstorming ideas about photosynthesis I think. (assessmentl knowledge)-**pPCK**

Researcher: Mmm.

Zandaya: And then what I also loved the prior knowledge of the learners it was considered by the teacher so yeah I think maybe like bring probably before we the teacher could have taught. Probably the teacher could have… I mean the teacher could have done brainstorming first before introducing. (pedagogical knowledge)-**pPCK**

Researcher: Oh, so you're saying that the teacher could have created the same mentimeter uh uh uh uh uh link. Learners they answer those questions maybe something similar that prior the lesson and then the teacher works on that and then again after the lesson.

Zandaya: Yes yes. That's brainstorming yes.

Researcher: Okay and then given the potential of smartboard to enhance interactive learning, would you recommend mentimeter as a tool to support the teaching of photosynthesis in a great level class and why?

Zandaya: Yes yes. I agree because firstly um it can support collaborative learning as as I've observed that learners they worked collaboratively and also it it the smartboard it actually provides real time insight to learners understanding and it is a valuable tool for teaching photosynthesis in grade 11 classroom and also I like the fact that it also caters for different learning styles of learners. It's so unfortunate that um the learners who can learn eh by touching, observing things in life. Yeah, I think those learners are excluded in the in the lesson. (pedagogical knowledge)-**pPCK**

Researcher: Oh Okay okay.

Zandaya: Yes. that's what I think Ma'am.

Researcher: Is there anything else that you would like to say or comment or ask in relating to the entire lesson regarding the integration of smartboard to to teach photosynthesis?

Zandaya: Uh I think um I'm struggling with um because I've noticed that the teacher you were able to create the poll and quizzes as well so um I would like to teach that to teach me. (pedagogical knowledge)-**pPCK**

Researcher: You mean the the mentimeter? Howe to?

Zandaya: Yes the mentimeter. Yes.

Researcher: Okay.

Zandaya: I would like to know more about that.

Researcher: Oh, you're not too familiar that much okay okay.

Zandaya: Yah that much but the lesson overall like it was very effective and I've seen learners were were really motivated. (pedagogical knowledge)-**pPCK**

Researcher: Okay Ma'am that will be all thank you

Zandaya: Okay thank you Ma'am.

APPENDIX 24: Sample of CAPS document

TERM 2

Strand 2: Life Processes in Plants and Animals

Organisms require energy to stay alive. They get this in one of two ways: by harnessing radiant energy from the sun and transforming it into chemical energy which they can use (autotrophs) or (if they cannot do this themselves), by eating other organisms (heterotrophs). The energy transformations that sustain life are include photosynthesis, (where energy is incorporated in to food), animal nutrition (where the food is processed so that it can get to the cells), and cellular respiration (how this energy is made available to organisms in order to stay alive). Gaseous exchange between an organism and its environment is necessary for photosynthesis and cellular respiration. Life processes also involve the removal of carbon dioxide and later the removal of nitrogenous wastes from the body through the kidney.

Time	Topic	Content	Investigations	Resources
3 weeks **(12 hours)**	**Energy Transformations to Sustain Life**	**Photosynthesis** • process of photosynthesis using words and symbols: the intake of raw materials, trapping and storing of energy, formation of food in chloroplasts and its storage. The release of oxygen. Mention only of light and dark phases *(no biochemical details of light and dark phases are required)*; • importance of photosynthesis: release of oxygen, uptake of carbon dioxide from atmosphere, food production (trapping energy); • effects of variable amounts of light, carbon dioxide and temperature on the rate of photosynthesis (brief discussion together with graphs). • The role of carbon dioxide enrichment, optimum light and optimum temperatures in greenhouse systems to improve crop yields *(link to environmental issues discussed later)*. • Role of ATP as an important energy carrier in the cell.	**Essential** • Investigate photosynthesis by showing that - starch is produced during photosynthesis; and - light is necessary for photosynthesis. • *The following investigations can be done (by learners) as experiments or as demonstrations:* - carbon dioxide is necessary for photosynthesis; - chlorophyll is necessary for photosynthesis - oxygen is produced during photosynthesis; or - data can be provided and interpreted by learners.	• Textbooks • Living plants • Suitable equipment • Chemicals

APPENDIX 25: Sample of ATP

2023/24 ANNUAL TEACHING PLANS: LIFE SCIENCES: GRADE 11

2023/24 ANNUAL TEACHING PLANS: LIFE SCIENCES: GRADE 11 (TERM 2)

TERM 2	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11
CAPS TOPICS	ORIENTATION	PHOTOSYNTHESIS (CAPS P. 42)			CELLULAR RESPIRATION (CAPS P. 45)		ANIMAL NUTRITION (CAPS P. 43)				
CORE CONCEPTS, SKILLS AND VALUES	Revise basic cell structure with focus on the chloroplast, leaf structure mitochondria and plant and animal tissues from grade 9 and grade 10 Revise basic photosynthesis and respiration from grade 8	**Process of photosynthesis** using words and symbols: The intake of raw materials, trapping and storing of energy, formation of food in chloroplasts and its storage The release of oxygen Mention only of light and dark phase **(no biochemical detail of light and dark phases is required)** **Importance of photosynthesis:** release of oxygen, uptake of carbon dioxide from atmosphere, food production (trapping energy)	Effects of variable amounts of light, carbon dioxide and temperature on **the rate of photosynthesis** **Improve crop** yields in greenhouse systems, role of ATP as energy carrier in the cell **ONE investigation** to explain the principles of the scientific process: Light is necessary for photosynthesis (Infuse investigation throughout the topic)		**Process of respiration: Aerobic respiration:** In cytoplasm and mitochondria, use words and symbols: glycolysis, Krebs cycle and oxidative phosphorylation **(no biochemical detail is required)**	**Anaerobic respiration:** Production of lactic acid in muscles during exercise, word and symbols **(no biochemical detail of process is required)**: The role of anaerobic respiration in the industry, e.g., beer brewing and bread making **Comparison** between aerobic and anaerobic respiration **TWO investigations** to explain the principles of the scientific process: O_2 is required by respiration, CO_2 is produced by living organisms during respiration (infuse investigations throughout the topic)	The **differences in dentition** for herbivorous, carnivorous and omnivorous lifestyles in terms of nutritional requirements and energy relationships (link with ecology – food chains) **Human nutrition** The **macro-structure** of the alimentary canal and associated organs and the **functions** of the different parts	The process of ingestion, digestion, absorption, assimilation and egestion and the significance of each: **Mechanical or physical digestion:** Types and functions of different kinds of teeth, processes of chewing Peristalsis **Chemical digestion:** Enzymes: functions of carbohydrases, proteases and lipases: Where produced, substrate, pH and end-products (Specific enzymes need not be named – link to enzyme activity)	**Absorption:** Small intestine as a region of most absorption of digested food, adaptations to increase surface area Structure (to tissue level) and significance of vili Importance of hepatic portal system in the transport of absorbed food to the liver and then through hepatic vein to the rest of the body **Assimilation:** Incorporation of glucose and amino acids, and the breakdown of alcohol, drugs and hormones **Egestion**	**Homeostatic control**, which involves the hormonal control of blood sugar levels (Links with Gr 12)	**Consolidation and revision**
PRE-KNOWLEDGE	CELL STRUCTURE: CHLOROPLASTS & LEAF STRUCTURE (GR 10)				CELL STRUCTURE: CYTOPLASM & MITOCHONDRIA (GR 10)		HUMAN SYSTEMS (GR 9)				
EXAMPLES OF INFORMAL/DAILY ACTIVITIES	**Activity** Draw and label diagrams of the leaf Indicate the functions	**Activity** Use a diagram of a plant indicating the intake of raw materials, trapping and storing of energy, formation of food in chloroplasts and its storage and the		**Activity** Use graphs to show effects of variable amounts of light, carbon dioxide and temperature on the rate of photosynthesis **Activity**	**Activity** Diagram of a cell with cytoplasm and mitochondria Use words and symbols indicating glycolysis, Krebs cycle and oxidative phosphorylation **Activity** The process of anaerobic respiration and the role it plays in the food industry. (Suggested as an investigation)		**Activity** Table with the differences in dentition for herbivores, carnivores and omnivores' lifestyles in terms of nutritional requirements and energy relationships	**Activity** Diagram of the human digestive system with labels and functions of each part Include mechanical and chemical digestion **Activity** Diagram of small	**Activity** Diagram of hepatic portal system explaining assimilation of products of digestion and breakdown of relevant substances **Activity** Schematic		

APPENDIX 26: Lesson Planning Notes.

6 June meeting

Features

Multimedia to be used => PowerPoint

Question

How to teach biological terms.

* Talk and write

to accommodate learners with spelling challenges

Probably ask prior knowledge from grade 8

SAMR Model

Quiz (Multiple choice)

5 Questions -> Posters

Group learners with no phones with those with phones

Modification -> Quiz.

Redefinition => Using any of the multimedia (words).

-> use a phone.

Second lesson -> Redefinition ->

Poster will be done in my absence.

Conclusion ->

Results ->

Add Slide -> activity where make a poster / power point.

Rubrics

Heroes' Day (Mozambique)

Week 5

To wrap up the lesson.

Where during the lesson will you ask a learner to come and draw a chloroplast and label it?

06 June Meeting

features →

Multimedia to be used → Powerpoint

Sino - Question

How to teach Biological terms

* Talk and write.

→ to accommodate learners with spelling challenges

TRAVEL LOG

Week 5

Probably - ask prior knowledge from grade 8.

SAMR Model

Quizz (Multiple choice)

5 questions → Router

Group learners with no phones with those with phones

Modification → Quizz.

Redefinition → Using any of the multimedia (Words)

use a phone

TRAVEL LOG

19 – June
Second lesson → Redefinition →

Poster will be done in my absence –

Conclusion →
Results →

Add slide → activity where make poster / PowerPoint ?

Rubric

feature → interactive education (IQ)

1. erase
2. use different
3. Different fonts.
4. save.
5. scroll down and up. / add a new Page.

45 minutes

Slide 3 → Identify the requirements of photosynthesis

→ ~~remove~~ adjust the last aim
→ put one slide

Slide 16 → add something the scale in the ecosystem, Food source.

21/6/2024
Reflection → feedback
→ Improve the lesson

Unique features in the smartboard ??

= Smart note book	Smart lab
= Recording	
= Drag	
= projecting visuals (But a projector can do this	
= Content can be modified / annotated without wiping of the old lessons	

Display ~~content~~ function

You integrate functions of the smartboard ~~next~~ the smartboard

Features of a smartboard → to go back and forth

(1) Touch and Stylus input

(2) Handwritting recognition

(3) Multimedia integration
multimedia content like videos
images, websites

(4) Ability to save and share content

(5) Eraser - to erase when a mistake is made

(6) Smart notebook → can allow more than one person to work

"Tell the truth, or someone will tell it for you." - Stephanie Klein

TRAVEL LOG			
START KM		TOTAL BUSINESS	
END KM		TOTAL PRIVATE	
		TOTAL KM	

Touch and Stylus input

Multimedia integration

Ability to Export file / All note will be saved

Digital ink to write

Multi-touch capability → recognize multiple touches

Split-screen functionality → teacher will have two screens, half

Smart notebook — to write and draw

Smart recorder — lessons will be recorded & saved.

Lesson planning

Voice Record → 2024/07/02

- The researcher made the first move by creating a power point presentation.
- Invited the teachers to a meeting to discuss the power point presentation
- The teachers decided on which features of Smartboard to use.
- smart note book
- The multimedia agreed on was the power point
- Agreed on more pictures/ diagrams than words
- Because with words learners lose interest easily and they write a bunch of notes without understanding them.

Use a picture of trees to extract learners prior knowledge ~~and use~~ the

- Some learners may say content related to photosynthesis and some may not

- As much as the focus as on smartboard integration we also need to remember the importance of the lesson / Photosynthesis In other word, do not forget to emphasise the content
- Researcher ~~shows~~ does have the adequate content knowledge because she was able to share it will the other teachers
- Writting down biological terms together with the learner to involve them in the learners.
- Teachers shared how they taught biological terms at their respective classroom.
- Writting ~~down~~ down the words for learners who struggle with spelling
- Agreed on linking learners everyday knowledge with content knowledge
- Ask learners questions from grade 8
- We took note of the idea that learners know the requirements of photosynthesis from

grade 8 but they do not know how those requirements are used to manufactured food because the ATP/ curriculum in grade 8 does not get into that

- for example, they know the word glucose but not the formula $C_6H_{12}O_6$
- Teachers took into Consideration what might appear in the exams that learners must know.
- The teachers agreed on recaping relevent content from previous grades like words word like autotroph taught in grade 8 and 10, the leaf structure taught in grade 10. This knowledge is greatly related to photosynthesis
- The teachers aggreed unitely that a whiteboard must not be used.
- Annotated on the powerpoint, especially ideas that pop up while you are teaching

29/8/2024

School 3

Meant meter → Annonymous Response??

→ few Questions?

→ modification or Redefinition

Google site

what level of SAMR

- Could it be?? How?,

Redefinition?..

Notes?? links?? meetings??,

forum??

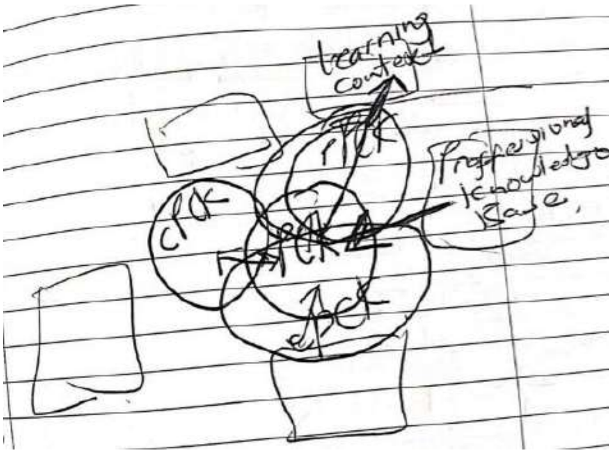
we it something create new

3:30
4:00
4:30
5:00
5:30
6:00
6:30
7:00
7:30
8:00
8:30
9:00

TRAVEL LOG

TOTAL BUSINESS

"I learned that courage was not


learning context
Professional knowledge base

APPENDIX 27: Informal Task on Starch Test

ACTIVITY

1. Why was the:
   - (a) leaf initially put in a beaker of boiling water? (1)
   - (b) Leaf boiled in alcohol? (1)
   - (c) Test tube with boiling alcohol placed inside a glass beaker with boiling water? (1)
2. Which colour change is observed in the leaf? (1)
3. Describe the results of this experiment? (2)
4. What conclusion can be drawn from this experiment? (1)
5. Write down the word and chemical equation for photosynthesis? (4)

Total [11]

CORRECTIONS

1. (a) Boiling the leaf in water softens it, kills the cells, and halts further photosynthesis.✓ (1)

   (b) To remove the leaf's chlorophyll with ethanol to make it easier to see the colour change that occurs when iodine solution reacts with starch. ✓ (1)

   (c) Ethanol is flammable, it is important to heat it using a hot water bath instead of using a Bunsen burner to achieve uniform heating with less fire hazard. ✓ (1)

2. Blue-black✓ (1)

3. There was colour change✓ in the iodine solution from reddish-brown to blue-black. ✓ (2)

4. The leaf tested positive for starch ✓ (1)

5. $$\text{carbon dioxide + water} \xrightarrow[\text{chlorophyll in leaves}]{\text{energy from light}} \text{glucose + oxygen}$$ ✓ ✓

   $$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$ ✓ ✓ (4)

Total [11]