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INVESTIGATING HOW MEANING MAKING OPPORTUNITIES MANIFEST IN BIOLOGY LECTURES BY TEACHER EDUCATORS AT A SOUTH AFRICAN UNIVERSITY

Nomzamo Xaba

A thesis submitted to the Wits School of Education, Faculty of Humanities, University of the Witwatersrand in fulfilment of the requirements for the degree of Doctor of Philosophy

Johannesburg

2025

ABSTRACT

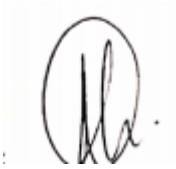
The motivation for this study stemmed from reflections on my personal experiences as a former pre-service biology teacher at a South African university. As a biology teacher educator, I now recognise that my most impactful lecture experience was where teacher educators engaged me in meaning making empowering me to support my students more effectively. In contrast, lectures where I learned little left me with knowledge gaps, requiring me to re-learn certain topics to engage the content meaningfully with my students. This realisation suggested a serious need for students to make meaning of the material shared in lectures hence the need to investigate the opportunities created by the teacher educators to enable meaning making in the classroom. Thus, this thesis aims to explore the manifestations of meaning making opportunities in higher education biology classrooms. While the construct of meaning making exists and has been widely researched, there has been no research that has focused on the manifestation of meaning making opportunities and their enactment in lectures. In this study, the concept of meaning making opportunities was explained as a teaching and learning 'chance' which permits the students to make sense of the knowledge presented. A meaning making opportunity was characterised by the manifestation of at least two forms of social exchanges (such as visual representations, writing and/or drawing, gestures and/or actions, and talk), with talk being a required component. Also, in this study, "manifesting" refers to the emergence and enactment of meaning making opportunities during biology lectures. It captures how such opportunities become observable in real-time through teacher educators planned strategies and spontaneous social exchanges, enabling students to connect new concepts with prior knowledge for meaningful learning. This thesis was underpinned by two primary theoretical frameworks namely, sociocultural theory and meaningful learning theory, which were selected for their complementary perspectives on learning as a social activity and cognitive development. Four biology teacher educators were purposefully and conveniently sampled from a South African university, and their teaching was observed. The data collection methods employed were video and audio recordings of the lectures, collection of slides used during the lectures, and Video Stimulated Recall Interviews. Data analysis included both deductive and inductive approaches which informed and strengthened the development of the analytical framework used in this thesis which led to a comprehensive understanding of how meaning making opportunities manifested in the biology lectures observed. Key findings from this study demonstrate that meaning making opportunities in biology lectures often do not always happen by chance but are the result of deliberate planning and the creative use of social exchanges. The results of this study also showed that by employing social exchanges in diverse combinations, biology teacher educators promoted the manifestation of a diverse range of meaning making opportunities. The study also found a direct relationship between the complexity of social exchanges, manifestation of meaning making opportunities and student engagement. Ultimately, this study advances the knowledge of how meaning making opportunities manifest in biology lectures and offers practical insights for teacher educators aiming to create meaningful learning experiences.

Keywords

Meaning making opportunities, teacher educators, social exchanges and student engagement.

DECLARATION

I declare that this thesis is my unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Nomzamo Xaba

14, February, in the year 2025

DEDICATION

To my grandmothers, especially my late grandmother Gladys Mathula Shezi, thank you for being my solid rock.

To my parents, words cannot express my gratitude for being my heartbeat and for your unwavering support through thick and thin.

To my siblings, especially Ayanda, *ngiyabonga mtase*.

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PRESENTATIONS EMANATING FROM THIS RESEARCH

Conferences Presentations

SAARMSTE 30th Annual Conference (Southern African Association for Research in Mathematics, Science and Technology Education). Symposium presentation on *Same teaching videos and same object of the study but different theoretical lenses: Studies of a teacher educator's teaching by postgraduate students.* Hosted by a Consortium of Western Cape Institutions: Cape Peninsula University of Technology (CPUT), University of Cape Town (UCT), University of the Western Cape (UWC), Stellenbosch University (SU), African Institute for Mathematical Sciences Schools Enrichment Centre (AIMSSEC) & Primary Science Programme (PSP) 18 –20 January 2022.

SAARMSTE 29th Annual Conference (Southern African Association for Research in Mathematics, Science and Technology Education). Snapshot virtual presentation on *An investigation of how biology lecturers in a south African teacher training program use language to engage pre-service teachers in the meaning making processes of their lectures.* Hosted by Lesotho Chapter and the National University of Lesotho 12- 15 January 2021.

SAARMSTE 28th Annual Conference (Southern African Association for Research in Mathematics, Science and Technology Education). Snapshot presentation on *Investigating biology lecturers' affordances to the promotion of meaning making in higher biology classrooms. Hosted collaboratively by Rhodes University and Nelson Mandela University and held at South Campus,* Nelson Mandela University, Port Elizabeth on 14-16h January 2020.

SAARMSTE Research School

18th Annual SAARMSTE Virtual Research School for Mathematics, Science and Technology Education Virtual Alternate Support Programme. Presenting the theoretical framework of the study *investigating opportunities that biology lecturers create to promote meaning making during instruction at a university.* Hosted by the School of Education, Sol Plaatje University Kimberley, South Africa 22 June - 21 July 2020

19th Annual SAARMSTE Virtual Research School for Mathematics, Science and Technology Education Virtual Alternate Support Programme. Presenting initial ideas for the proposed study *investigating opportunities that biology lecturers create to promote meaning making during instruction at a university.* Hosted by the Future Africa Centre, Hatfield Pretoria, South Africa 03 - 06 July 2019

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LIST OF ABBREVIATIONS

2D: Two-Dimensional
3D: Three-Dimensional
B.Ed.: Bachelor of Education
BSc Hons: Bachelor of Science with Honours
BSc: Bachelor of Science
CIRC: Cooperative Integrated Reading and Composition
cPCK: collective Pedagogical Content Knowledge
D.Ed: Doctor of Education
DNA: Deoxyribose Nuclear Acid
ePCK: enacted Pedagogical Content Knowledge
ER: Endoplasmic Reticulum
FAL: First Additional Language
FDBK: Feedback
G/A: Gestures and/or actions
HE: Higher Education
HoDs: Heads of Departments
IRF/E: Initiation, Response, Feedback/Evaluation
LE: Lecturer Explanation(s)
LMS: Learning Management System
LS: Life Sciences
M.Ed.: Masters in Education
FET: Further Education and Training
MLT: Meaningful Learning Theory
MMO: Meaning Making Opportunity
MSc: Masters in Sciences
NS: Natural Sciences
OTL: Opportunities to Learn
PCK: Pedagogical Content Knowledge
PGCE: Post Graduate Certificate in Education
PhD: Doctor of Philosophy
PLM: Pedagogical Link Making
pPCK: personal Pedagogical Content Knowledge
PRAC: Postgraduate Research Authentic Conversations
PST(s): Pre-service Teachers
Q: Question(s)
RCM: Refined Consensus Model
SAARMSTE: Southern African Association Research in Mathematics, Science, and Technology Education
SAX: South African University
SCT: Sociocultural Theory
SEs: Social Exchanges
T&L: Teaching and Learning
TE(s): Teacher Educator(s)
TSPCK: Topic-Specific Pedagogical Content Knowledge
VARK: Visual, Aural, Read/write, and Kinaesthetic
VR: Visual representations
VSRI (s): Video Stimulated Recall Interview(s)
WIL: Work Integrated Learning
WRTN: Writing and/or drawing

Chapter 1

Overview of the study

1.0.Introduction

This chapter provides an overview of the problem that was investigated in this study and provides the background, research problem, context of the study, researcher's positionality, aim, research questions, contribution of the study and outline of the thesis.

1.1. Background

Biology teacher education in South Africa faces persistent challenges in fostering deep conceptual understanding among pre-service teachers, despite policy shifts encouraging constructivist and student-centred pedagogies (see: Department of Higher Education and Training [DHET], 2019; Loughlin & Lindberg-Sand, 2023; Scott & Mortimer, 2012). Effective biology instruction requires more than the transmission of content; it involves deliberately structuring opportunities for students to engage in the process of meaning-making, which involves active construction of understanding through interaction, reflection, and application (Vygotsky, 1978; Chi & Wylie, 2014).

As I reflect on my time as an undergraduate Bachelor or Education (B.Ed.) student at a South African University (henceforth, SAX), I vividly recall biology teacher educators who engaged me in ways that made me understand the content better. These teacher educators used a range of teaching strategies such as analogies, demonstrations, probing questions, and open-ended class discussions. These teaching strategies not only enhanced my understanding of the biology content but also instilled confidence in my ability to understand complex ideas, making it easier to complete related activities like tutorials, tests, and practical investigations. What stood out was the lively engagement among pre-service teachers during and after these lectures, where discussions would often continue as we left the venue, energised by our shared understanding of the content presented and/or learned. However, not all lectures were like this. In some instances, I left the lecture hall feeling lost and overwhelmed by complex jargon and teaching methods that did not facilitate any understanding of the content presented. This led to a gradual disengagement, with many of us (the undergraduate students at that time) opting to skip such lectures entirely, feeling they were a waste of time. After completing my undergraduate studies before resuming this doctoral journey, I began to wonder about the current state of biology instruction and how effectively pre-service teachers were being engaged in meaning making processes.

Through my review of higher education literature, I observed a gradual shift in pedagogical approaches among lecturers, transitioning from traditional methods to more constructivist practices, particularly at

the undergraduate level and across various disciplines. A study conducted by Loughlin and Lindberg-Sand (2023) reported that the implementation of constructivist educational changes has been particularly challenging, especially in introductory first-year modules. These challenges include but are not limited to large classes, limited weekly meeting times, complex and overwhelming content and traditional 'transmissive' methodologies used by most lectures (Silverthorn et al., 2006). According to Tanner and Allen (2005) when faced with the above-mentioned challenges, most teacher educators tend to spend more time lecturing the content rather than creating authentic opportunities that engage students with the content. Lunsford and Diviney (2020) have termed this approach as 'breadth over depth', which they also believe is the main cause that many university students have a superficial understanding of their subjects of specialisation. Lunsford and Diviney (2020) argue that this 'breadth over depth' teaching and learning (T&L) approach poses a 'danger' particularly in teacher professional development programmes. Thus, Lunsford and Diviney (2020) propose that teacher educators need to implement active T&L strategies that will involve their pre-service teachers in meaningful learning aimed at strengthening their conceptual understanding of the content. This is particularly important in higher learning contexts because the pre-service teachers need to gain mastery of the content as well as the expertise necessary for them to cope in their future professional roles.

As earlier indicated, it has been 4 years since I completed my undergraduate studies, and probably much has changed since then. I thus conducted a pilot study to see how biology teacher educators are currently involving their pre-service teachers. The analysis of the pilot data affirmed some of my past experiences that some biology teacher educators are still lecturing for meaning making purposes, and such instances were marked by 'chances' that engage students in the meaning making processes of the lesson, while others are still not. I began to wonder why this continued to persist. Was it because some biology teacher educators are aware of the importance of creating opportunities that engage their students in meaning making while others are not? This was the motivation for this study which aims to investigating how meaning making opportunities (MMOs) manifest in biology lectures by teacher educators at a South African university.

Although extensive literature exists on meaning-making, sense-making, and opportunities to learn (e.g. Tang et al, 2014; Scott &Mortimer, 2012). What I noticed was that the studies on meaning making and sense-making often present it as the product rather than a process of learning. On the other hand, the concept of opportunities to learn, as framed in the literature, highlights learning as a generic process influenced by a myriad of factors such as instructional quality, student engagement, socio-cultural factors, and access to resources, which are often not packaged as instructional toolkits. While there seems to be an expectation for teacher educators to engage their students in opportunities that promote meaning making, there seems to be no existing research on this specific concept. This gap in the literature motivated me to focus my study on investigating how meaning making opportunities manifest

during biology lectures. While this gap presented an exciting research opportunity, it also posed a challenge, as I did not know how to proceed with the study. I first had to be clear with what I meant by a meaning making opportunity in the context of this study, as a result, it was therefore conceptualised as any instance where students are given the 'chance' to make sense of the knowledge being presented. This 'chance' that marks the manifestation of a MMO is evidenced by various forms of students' engagement such as note writing and responding to a question to mention a few examples. A meaning making opportunity in this study was characterised by the co-occurrence of two or more social exchanges such as visual representations, gestures, or actions alongside talk since they framed the studies analytical framework. These social exchanges were therefore used in this study to document the manifestation of meaning making opportunities in biology lectures at SAX. In this study, a meaning-MMO was characterised by the co-occurrence of two or more social exchanges, such as visual representations, gestures, or actions in combination with talk. This operationalisation was informed by sociocultural theory, which views learning as mediated through multiple semiotic resources (Vygotsky, 1978; Wertsch, 1991) as explained in greater details in Chapter 2. Prior research in science education similarly highlights that meaning emerges not only from language but through the integration of talk, writing, bodily actions, and other material artefacts (Lemke, 1998; Kress et al., 2001). Building on these ideas, the study adopted the SEs as multimodal tools for systematically documenting the manifestation of MMOs in biology lectures at SAX.

Defining the concept 'manifestation'

In this study, the term 'manifestation' refers to the ways in which MMOs become visible, observable, and enacted during biology lectures. Manifesting is not understood as a fixed outcome but as a dynamic process that emerges through the interplay between teacher educators' pedagogical decisions, students' responses, and the social exchanges (talk, gestures, actions, visual representations, etc.) that mediate learning (Vygotsky,1978). From a sociocultural perspective, to say that an MMO "manifests" means that it comes into being in concrete classroom interactions, through planned strategies (e.g., use of models, analogies, questioning, eliciting prior knowledge) as well as unplanned moments (e.g., spontaneous discussions, clarifications, or addressing misconceptions). Within the framework of meaningful learning theory (Novak, 2002), manifestation signals the point at which teaching practices create conditions for learners to connect new biological concepts with their prior knowledge in ways that promote understanding, rather than rote memorisation.

1.1.1. The Structure of the Teacher Education Programme at SAX

This study was conducted at a School of Education at SAX. During the time that this study was conducted, the teacher professional development programmes at SAX comprised of four streams: (I) **Teaching Subjects/Academic Stream** that focuses on teaching content subjects such as science, English, geography, and mathematics. (II) **Core Subjects Stream** which focuses on subjects such as

sociology and psychology of education. (III) **Methodology Courses Stream** that are subject-specific, teaching pre-service teachers how to teach their specialised content subjects (Nyamupangedengu, 2015). For instance, a student majoring or specialising in Life Sciences must complete a course called Secondary Methodology of Life Sciences. (IV) **Teaching Experience Stream** where pre-service teachers are placed in schools for two three-week sessions annually to practice teaching. Nyamupangedengu (2015) further explains that despite the pre-service teachers' phases of, they all study the same content subjects. However, there are distinct methodology courses for secondary and primary school teaching. At SAX, the academic or teaching subjects stream seeks to strengthen teacher professional development by deepening pre-service teachers' content knowledge and conceptual understanding of their specialisation (Nyamupangedengu, 2015). Within teacher education, this process is not about passive transmission of knowledge, but rather the intentional cultivation of disciplinary competence that forms the foundation for pedagogical content knowledge and lifelong professional learning (Nyamupangedengu, 2015).It includes two 'learning areas' studied over two years, followed by the extension of two content subjects—one studied for an additional two years as an academic major and the other for one additional year as a sub-major. Table 1.1. below shows how Natural Science (NS) as a learning area in the academic subjects' stream can be further perused as Life Sciences (termed as Biology throughout this study) as an academic major or sub-major.

Table 1.1. An overview of the Natural and Life Sciences B.Ed. programme structure at SAX

	Year 1	**Year 2**	**Year 3**	**Year 4**
Teaching subjects	Natural Science I (NS) (Learning area)	Natural Science II	Life Sciences III (LSIII)	Life Sciences IV (LSIV)
Second teaching subject I (in a different learning area e.g. Mathematics	Second teaching subject II		Second teaching subject III	
Core subjects	Education I	Education II	Education III	Education IV
Methodology subjects	Secondary methodology NSI	Secondary methodology NSII	Secondary methodology LSIII	Secondary methodology LSIV
Teaching Experience (TE)	TE I	TE II	TE III	TE IV

*List of abbreviations used in the table: **B.Ed.**: Bachelor of Education; **NS**: Natural Science; **LS**: Life Sciences; **TE**: Teaching Experience

Note that the structure of the B.Ed. program is illustrated using both Natural and Life Sciences subjects because the study is interested in documenting the manifestation of meaning making opportunities in these lectures.

1.2. Problem statement

As earlier alluded, there are discrepancies in how biology teacher educators teach their pre-service teachers at SAX. While some biology teacher educators rely on traditional lecturing styles that prioritise content transmission, others seek to promote MMOs that move beyond mere delivery. Such opportunities acknowledge that meaning making does not occur in a vacuum but is shaped by interactions happening in the lecture, cultural contexts, and the use of mediating tools such as language, gestures, and visual representations. Even so, in the South African context, there are limited studies that have paid attention to studying lecturers' T&L strategies that they use to promote meaning making opportunities in their lectures. As a result, not much is known about whether or not biology teacher educators engage their pre-service teachers in meaning making opportunities across South African Universities. This lack of research can be explained by the assumption that lecturers have a wide range of knowledge and skills in their fields of specialisation and are often assumed to 'know what they are doing' (Fraser, 2013). However, the Department of Higher Education and Training (DHET, 2019), alongside Booi and Khuzwayo (2019) and Beets (2009), highlighted inadequacies in teacher education programmes, particularly in mathematics and science. These inadequacies are both curricular, relating to what disciplinary knowledge is prioritised and how deeply it is developed and pedagogical meaning that they concern how teachers are prepared to enact that curriculum responsively in diverse classrooms). The DHET National Framework for Enhancing Academics as University Teachers (2018) explicitly highlights this dual challenge, emphasising the need for curriculum renewal alongside the strengthening of pedagogy through continuous professional development, recognition, and teaching-focused communities of practice. This study contributes to that agenda by investigating how meaning making opportunities (MMOs) manifest in biology lectures by teacher educators at a South African university.

These sources indicate that current teacher programs are failing to produce teachers who can adapt to curriculum changes due to their lack of capacity and competence in manipulating their subject matter knowledge to suit the context of the schooling environment. This shortfall underlines a critical gap in teacher preparation, specifically in developing methodologies that help pre-service teachers to be in a position to promote meaning making opportunities that engage their future learners. Given this context, it became essential to investigate how meaning making opportunities manifest in biology lectures. This focus on documenting manifesting meaning making opportunities in biology was deemed crucial in potentially identifying instructional methods that can promote meaning making in biology teacher education lectures.

1.3. Positionality

1.3.1. My background as a researcher: who I am and where I come from

I am the eldest in my family, with two brothers and two sisters. I was born in Loskop, a small town in Estcourt, KwaZulu-Natal. I was raised by my maternal grandmother and aunts while my mother was completing her studies. At the age of four, I moved to Johannesburg with my paternal grandmother, who worked as a domestic worker. We moved frequently due to her various odd jobs. Johannesburg was a completely new world for me, and it was the first time I saw towering buildings, and many white people, and heard a variety of languages. Growing up in KwaZulu-Natal, where IsiZulu was the norm, I had assumed it was the only language that was spoken by everyone.

In the homes where my grandmother worked, I often played with the white children. Initially, I barely understood what they were saying, and my grandmother would often translate for me. However, through constant interaction, I quickly picked up the English language and no longer needed her translations. When we later moved to neighbourhoods like Yeoville, Hillbrow, and Berea, which were areas not dominated by white residents, I was introduced to a new communal way of living, surrounded by people from different African countries. English continued to be a common language in this new environment, but I could tell by their distinct accents that they came from various parts of Africa. This experience made me realise that English served as a unifying language, bridging the gaps between us, as none of us spoke or even understood each other's native languages.

During the December holidays, I would often return to Loskop to visit my mother and her family. I would be so excited to go as it would give me an opportunity to share stories from the city with my cousins and friends. However, they preferred my stories to be narrated in isiZulu, as English was foreign to them, and they did not like the language much. Yet, when television became a little bit popular in the rural areas and we had a chance to watch cartoons and/or movies, and they would eagerly ask me to translate. This revealed how English, though alien in Loskop, still found its way in and served some purpose. I realised the importance of exposure in discovering and learning new languages.

Leaving Loskop to go back to Johannesburg was always a bittersweet experience, but I eagerly looked forward to reuniting with my paternal grandmother. During my time with her, I did not attend any formal pre-school. Instead, she home-schooled me despite only having completed school up to Standard 2 (now referred to as grade 4 in the South African context). She taught me how to read and write in both English and IsiZulu, as well as introduced me to fascinating books about science, art and many other disciplines. She was an exceptional storyteller and delighted me with captivating tales just before bedtime. She truly laid the foundation for my academic journey, and I remain eternally grateful for instilling in me the value of education and a teachable spirit. It broke my heart when she fell ill and had to leave the city and return to Loskop.

My grandmother's illness and return to Loskop, meant that I had to now go live with my parents for the first time in my life in Soweto and this was about the time when I was just reaching school-going age (about 7 years old). Attending school in Soweto introduced me to yet another culturally and linguistically diverse environment. In Soweto, my parents and I lived in backrooms and again we moved frequently, which exposed me to various native linguistic communities such as seTswana, seSotho, isiXhosa, tshiVenda and xiTsonga speakers. Although these were South African languages, they were still unfamiliar to me, and it was surprising that many people in these areas like my cousins and friends back in Loskop had negative attitudes towards the English language, which made it difficult for me to 'fit in'. I was labelled a 'coconut' for speaking English because they also did not speak isiZulu, and this made forming friendships a serious challenge. I quickly realised that learning these new languages was essential for me to belong in these environments, but just as I started to learn one, my parents and I would have to move, forcing me to start over. These experiences taught me that language is indeed a symbol of social capital and power as argued by Bourdieu (1991), because it dictated whether one was an insider or outsider in any given context. By the time I reached high school, a multicultural environment, my ability to speak various languages allowed me to interact with anyone, unlike in my earlier years when language created cliques and divisions.

1.3.2. My journey: From University pre-service Teacher to University Teacher educator

My undergraduate experiences

After completing my matric in 2010, my parents were thrilled to see their first child being accepted and awarded a bursary to study at SAX. This was an incredibly memorable year for me, as I had long dreamed of this moment during conversations with my paternal grandmother. When it finally happened, it was beyond my wildest imagination. In 2011, as a first-year undergraduate at SAX pursuing a Bachelor of Education in Further Education and Training (FET) with a major in Biology and a sub-major in English, I encountered English as the dominant language in all my modules. Despite my confidence in English, I soon felt uncomfortable speaking it around peers who had more polished and affluent accents. For the first time, I became self-conscious about my language skills, because in Soweto schools, we learned English as a First Additional Language (FAL), often taught in whatever native language the teacher spoke. During group work at SAX, I gravitated towards other black students who had similar accents to mine. Yet, even within these groups, I rarely contributed verbally but would often silently critique others' ideas while struggling to express my own.

During my teaching experience (also known as work integrated learning, WIL), I usually chose schools in Soweto where I could comfortably switch between English and local languages. Despite this flexibility, many learners struggled with biology and disliked using English, which was the medium of instruction. I often attributed their difficulties to passing biology to having to write the assessments in

English, where they also had limited proficiency in. However, there were times when schools in Soweto could not accommodate us, and the teaching experience officer at SAX would place us randomly in available schools. On one occasion, I was assigned to a multiracial school, and another time to an Indian-dominated school, both located in neighbouring urban areas to Soweto. In these settings, I was surprised to see that most learners, even those who were native English speakers still struggled with understanding and passing biology. These experiences taught me that biology has its own specialised language, which poses challenges for both native and non-native English speakers. I soon realised that teaching biology was a more difficult task than I thought, as most learners would often look bored during the lessons. But, when I tried different methods which I also found useful in my experiences, like using analogies, crosswords, videos and debates to mention a few, they seemed intrigued and engaged in the lessons. These experiences challenged me to constantly try to find different ways of making the content not just understandable but relatable and engaging to my students, which often required a lot of work and time.

My experiences as a postgraduate and early career as a biology teacher educator

The truth is that I had never aspired to pursue postgraduate studies. My primary goal was to complete my undergraduate degree quickly, become the first graduate in my family, and start working to support my family financially. I remember during my final year at SAX conversing with peers who were doing their Honours at the time, and they advised me to start job hunting and apply for an Honours degree as a backup plan in case I did not find a job. Fortunately, in 2015 after graduating, I managed to secure a contract position at a school in Soweto, where I taught English and Natural Sciences. However, during the third week of the first term, I received a call from a lecturer at SAX inquiring whether I was still interested in pursuing my Honours degree. At that moment, I had completely forgotten about the application. Amidst managing my class, I hastily accepted the offer so I could quickly return to monitoring my learners. When I got home, it struck me that I had committed to returning to SAX as a full-time student for a Bachelor of Science in Education with Honours. I started to panic about the abrupt decision, realising that I had become one of the primary breadwinners at home since my mother was unemployed and my father's job only covered rent and food. Even so, the teaching position was only a short-term contract, leaving me with the looming question of what I would do once it ended.

After weeks of keeping the news to myself. I gathered the strength to tell my parents the news as I carefully observed their faces. To my surprise they did not seem sad or disappointed rather they seemed excited. They assured me that this opportunity seemed more stable than the current teaching post and what would make them sad was seeing me at home unemployed. I was relieved, that night I slept peacefully. I went to SAX later in the week to enquire further about the program and this helped me because I realised that I could still manage to finish the term at the school before committing full-time to my studies. This appeared like a doable and practical plan since our classes occurred late in the

afternoon until the evening. This gave me time to travel from the school to the campus. In the first week of February 2015, classes began and to my surprise, there were only eight of us in the class. This meant that I could not hide behind others anymore as we had discussions, seminar presentations and many other interactive activities that required us to demonstrate critical engagement with the materials given in the lectures. To add to the problems, I was confronted with academic literature, and we were expected to write academically which I found to be different from everyday spoken and written English. Although navigating this new form of communication felt like scaling a mountain, it became an exciting adventure which I am still grappling with to date. Despite the challenges, I learnt a lot in these lectures and got an opportunity to investigate the problems I encountered as a new in-service teacher. For my Honours research project that year, I undertook a study entitled 'Investigating the role of code-switching in science classrooms". The study yielded very interesting findings about the advantages and disadvantages of code-switching in science classrooms.

In 2016, I found myself as a full-time registered student for a Masters in Science Education program at SAX again by default. Although I was regaining my confidence in speaking the English language during discussions, I still lived in my head most of the time. This time around, I was interested in understanding whether or not the training program at SAX adequately prepares preservice teachers with the appropriate disciplinary knowledge required to teach their subjects of specialisation. Thus, I conducted a study entitled "Investigating 4th-year pre-service teachers' levels of understanding of the disciplinary nature of Life Sciences as a discipline" which I passed with a distinction, and it saw me qualifying for the doctoral degree.

I started the doctoral degree in 2018, during that year I was with a different supervisor, and I proposed that I would look at the role of language in supporting meaning making in biology classrooms. This was after seeing that the findings in my Masters revealed that the teacher training at SAX is content-focused but the questions that remained unanswered were how the preservice teachers were supported to understand this content and whether or not the pre-service formulated meanings or simply memorised the content learned. However, after the supervisor left the institution, as a result, the focus of the study shifted to investigating meaning making opportunities that manifest during biology lectures. Conducting this study was further motivated by my current role as a biology teacher educator at a rural university in KwaZulu-Natal. When I first started, although there was an induction, there was no formal training provided on what was expected from me in this position. I had to navigate and figure things out on my own. The transition from an urban area to a rural one was particularly challenging, despite being born in KwaZulu-Natal, as I had spent most of my life in the city. This personal experience fuelled my interest in exploring how meaning making opportunities can be better understood and supported in biology education. Given that, when I look back on my own initial teacher training program, I now realise how the positive lecture experiences I had as a student empowered me and shaped my current

teaching practices, while the negative ones had a crippling effect, limiting my confidence and teaching approaches. For instance, the topics that I thoroughly understood during my university lectures are far easier to teach effectively compared to those I merely memorised to pass exams. The topics I struggled with as a student, I now find myself investing significant time in re-learning the content to be in a better position to teach it in a way that my students can better understand, although I am sometimes tempted to just read what I have on the slides. However, my goal is not merely to pass on knowledge, but to discover innovative ways to engage my students who are also future teachers themselves, enabling them to genuinely understand the content rather than simply memorising it, thus the motivation for conducting this study. I believe that it is important for teacher educators to engage students in opportunities that permit them to formulate meanings to break the cycle of pre-service teachers with superficial knowledge of the content of their specialisation as proposed by Lunsford and Diviney (2020). This is particularly important, especially in the South African context where the biology matric pass rate has been consistently worrisome (Department of Education, 2024). However, this has not been an easy task because at times I would not know where to begin as different biology topics differ in complexity and require different teaching approaches which are sometimes not documented in the literature.

1.4. Aim of the study

The aim of this study is to investigate how biology **teacher educators** at SAX facilitate the manifestation of MMO) during their lectures, given that meaning making is one of the most fundamental building blocks of effective science education (Scott & Mortimer, 2012). By examining lecturers' pedagogical actions, decisions, and interactions, this study seeks to understand the processes through which MMOs emerge, how they engage students, and the contextual factors that shape their occurrence.

1.5. Research questions

The study is guided by one main research question and three sub-research questions as detailed below.

Main research question

How did biology teacher educators facilitate the manifestation of meaning making opportunities during their lectures?

Sub-questions

1. *What meaning making opportunities were facilitated by biology teacher educators in their lectures?*
2. *What forms of student engagement (if any) were elicited by the biology teacher educator during the manifesting meaning making opportunities?*
3. *What were the factors that promoted or hindered the manifestation of meaning making opportunities that were facilitated in the biology teacher educators?*

1.6. Contribution of this study

This study contributes to science education research by addressing the gap in understanding how MMOs manifest in biology lectures. The study seeks to shows how biology teacher educators facilitate the manifestation of MMOs, which then elicit various forms of student engagement these opportunities elicit, and the factors that promote or hinder them. In doing so, the study clarifies the role of MMOs as critical mechanisms through which students are supported to move beyond rote learning toward deeper understanding and more meaningful engagement with biology content. Therefore, the findings from this study will not only help assess current teaching practices but also identify teaching and learning strategies that support the manifestation of meaning making opportunities, offering guidance for refining pedagogical approaches in biology education. Moreover, this study can help biology Heads of Departments (HoDs) to plan and conduct professional development workshops that focus on equipping lecturers with strategies to facilitate meaning making opportunities and foster deeper student engagement with biology content. This might assist teacher educators to think about innovative ways in which they can engage their pre-service teachers in meaning making opportunities that will help them better cope with the teaching and learning demands of their subject of specialisation. Such initiatives might result in effective biology teaching and learning practices within higher learning institutions as well as in secondary schooling contexts. Involving students in meaning making opportunities has the potential to enable them to develop content mastery and acquire higher-order thinking skills.

1.6. Outline of the thesis

Chapter 1 provide an overview of the scope of the problem investigated in this study and is outlined in the previous subsections.

Chapter 2introduces key theoretical frameworks, including Sociocultural Theory (SCT), Meaningful and Learning Theory (MLT), which provides a comprehensive understanding of the processes underlying meaning making, learning and cognition. Following these theoretical groundings, the review further explores the conceptualisation of meaning making, opportunity (MMO), focusing on its relationship with discourse, language, and teacher knowledge. This chapter further explores the role of mediation in facilitating meaning making, again emphasising the significance of language, talk, and discourse in the classroom environment.

Chapter 3 outlines the research methodology employed in the study. It begins with a description of the research paradigm and design, followed by an outline of the study sample and recruitment procedures. The chapter then details the data collection instruments and techniques used, alongside a discussion of ethical considerations and the strategies implemented to ensure trustworthiness, credibility, and rigour.

Finally, it presents an overview of the data analysis procedures, demonstrating how the collected data were systematically interpreted to address the research questions and objectives.

Chapter 4 describes the development of the analytical framework. The constructs of social exchanges (SEs), student engagement and learning preferences which were central to the development of the analytical framework for studying meaning making opportunities during biology lectures. Therefore, in this chapter, an explanation of the centrality of these concepts are provided. The chapter explains the fundamental relationship between the analytic framework and the research questions, illustrating how it guides the selection of relevant data to address the study's research questions.

Chapter 5 presents Case Study 1 based on Dr Chris's Cell biology lectures to 1st year Natural Sciences students.

Chapter 6 introduces Case Study 2 based on Dr Molly's lectures on mitosis and animal tissues to 3rd year biology students.

Chapter 7 introduces Case Study 3 based on Dr Moses' excretion and osmoregulation lectures presented to 3rd year biology students.

Chapter 8 introduces Case Study 4 based on Dr Ellen's genetics and meiosis lectures presented to 4th year biology students.

Chapter 9 presents a cross-case analysis approach to further examine any significant parallels and/or distinctions that exist between the already documented MMO types that manifested across the four biology lectures. This comparative analysis approach is deliberately used in this chapter to gain insights into any significant implications associated with the use of the SEs and manifesting MMO types that appeared across the four lectures regarding meaningful biology education teaching. The chapter concludes by offering insights aimed at answering the research questions of the study. **Chapter 10** highlights the key conclusions, limitations, and recommendations for future research.

1.7. Conclusion

This chapter provided an overview of the problem researched in this study. The next chapter focuses on reviewing the literature that is central to the study's problem, as well as the theoretical frameworks that underpin the study.

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[1] In this study, the terms teacher educator(s) and lecturer(s) were used interchangeably, as were the terms preservice teacher(s) and student(s).

Chapter 2

Literature review and theoretical frameworks

2.0. Introduction

The central focus of this study was to investigate the manifesting MMOs in biology undergraduate lectures presented by four biology teacher educators that participated in this study. An overview of the scope of the problem of the study was outlined in the previous chapter. This chapter begins by introducing the key theoretical frameworks, including Sociocultural Theory (SCT), Meaningful and Learning Theory (MLT), which all provide a comprehensive understanding of the processes underlying meaning making, learning and cognition. Following these theoretical groundings, the review explores the conceptualisation of meaning making, opportunity, and MMOs, its relationship with discourse, language, and teacher knowledge. It explores the role of mediation in facilitating meaning making, again emphasising the significance of language, talk, and discourse in the teaching and learning environment.

2.1. Theoretical framework: Sociocultural Theory

A theoretical framework serves as a 'tool' that is underpinned by a theory or set of theories (Bingham et al. 2024). It encompasses the fundamental ideas and beliefs held by a researcher regarding the phenomenon that is being closely studied (Bingham et al.,2024). This study is grounded in the Sociocultural Theory (SCT) perspective, as it aims to investigate how meaning making opportunities manifest in biology lectures. SCT originates in Vygotsky's work which dates back to the 1970s and has evolved into a widely useful theory across various fields, particularly in psychology (Glăveanu, 2020) and education (Leung, 2023). SCT remains highly relevant in current literature as it highlights the role of cultural tools, language, and social interactions in fostering cognitive development, leading to meaning making in social contexts (Plakitsi et al., 2024; Gavelek & Bresnahan, 2014). The social context refers to the presence of others (the biology TEs and students). According to Siry et al. (2012), science, including biology, is inherently both embodied and enacted, meaning it is practised through social interactions facilitated by 'talk' within institutional and cultural frameworks (Lemke, 2001). Thus, constant interactions or 'talking' with others results in meaning making (Gavelek & Bresnahan, 2014). Engaging in dialogue not only involves exchanging ideas but also modifying and revising individual understandings within a social context. Gavelek and Bresnahan (2014) and Siry (2011) suggest that within the SCT perspective, meaning making is extensively characterised by the teacher's acknowledgement of learners' prior knowledge as rich resources. These resources in this study became important as they can be drawn upon to facilitate MMOs, as they have the potential to enable pre-service teachers to 'talk' during engagements and further develop their existing knowledge structures. Thus, some authors (e.g. Plakitsi et al., 2024; Furberg et al., 2009) advocate for the use of SCT in modern-

day research. The SCT is suitable for framing this study that seeks to understand how MMOs manifest in biology lectures.

The above section emphasises that the SCT perspective, suggests that knowledge construction primarily unfolds through social interactions. In this study therefore, knowledge construction unfolded when teacher educators and pre-service teachers are 'talking' about the content. Thus, the subsequent subsection aims to explore how 'meaningful learning' is mediated by language and other social tools, thus the concepts of mediation, language, and discourse are explored in greater detail below.

2.2. The role of Mediation in Meaning Making Opportunities (MMOs)

Jonassen et al. (2004) and Vygotsky (1989) argue that meaningful learning that leads to the construction of new knowledge occurs on two levels. Firstly, understanding appears on the social level, that is between people which is a key feature of the dialogic nature of understanding. Secondly, understanding appears in the individual plane, happening inside a person's mind. This is known as "the path along which the cultural development evolves" (Vygotsky 1989, p.18). For biology teacher educators to be able to engage pre-service teachers in MMOs that enable them to construct and internalise the new knowledge learnt can be mediated through a set of cultural tools. Hence, Kozulin (1990) argues that mediation is the mechanism through which external, socio-cultural activities are transformed into internal and mental functioning. Mediation, as suggested by Kozulin (1990) is a device of cognitive change. For this cognitive change to happen, Mercer and Littleton (2007) say that language (discussed in sub-section 2.3.1 below) and other cultural artefacts (e.g. handouts or notes, DNA model, and many others) are tools that can be used for guiding and supporting the thinking processes of individuals during learning. Mercer and Littleton (2007) call this interactional experience 'inter-thinking', and the basic premise is that thinking that results in meaning making and in the development of higher cognitive reasoning is facilitated by social interaction (Appel & Lantolf,1994).

2.2.1. Perspectives on Language in Mediation

As earlier explained, within the SCT perspective, language plays a central role as a cultural tool that mediates social interactions and cognitive processes (Mercer & Littleton, 2007). Through using language, individuals can negotiate meanings, share perspectives, and co-construct knowledge within social contexts (Chun et al., 2022). Meaning making, in existing studies have shown that language means different things to different scholars. A broad spectrum of views exists today in publications on language in education, although this study will only focus on two key viewpoints where language is viewed as (i) cognitive and (ii) social tools, further explained in greater detail below. These two key perspectives on language were particularly suitable because they align with both theories that underpin the study which are the SCT and the meaningful learning theory.

The first view is represented by authors such as Cohen et al. (2004) who frame language as a **cognitive** or **ideological tool** that brings about meaning in science teaching and learning. Tomasello (2008)

regards language as a mental arrangement of symbols for coding and deciphering information which are critical processes that lead to the possible internalisation of knowledge during MMOs. One disadvantage that can be linked to Tomasello's (2008) viewpoint on biology T&L is that it inappropriately regards language as an abstract construct, and not as a tangible resource that can be used by teacher educators alongside their pre-service teachers to jointly share ideas during MMOs. This can result in an enhanced understanding of content by the students. The advantage of the above-mentioned view on language is that it emphasises the importance of how teacher educators can use language to shape their pre-service teachers' ideas about the biology content during MMOs. Once these mental representations are moulded within the pre-service teachers' cognitive structures, they can be expressed in various forms of discourse which could either be verbal and/ or non-verbal and have the potential to foster collaborative MMOs in biology classrooms or lectures.

The second perspective on language is represented by a second group of authors (e.g. Thorne, 2013; Vygotsky, 1978; Wellington & Osborne, 2001) who regard language as a **social** or **epistemological tool** used to establish meanings. This view suggests that pre-service teachers acquire language through their everyday life experiences, and this shapes how they construct meaning when learning biology content (Thörne et al., 2013; Vygotsky, 1978). Thus, Zittoun and Brinkmann (2012) view language as an essential component of not only MMOs and meaning making but that of social identity, and cultural practices. Within the South African context, the issues of students' language diversity and the language of the medium of instruction persist to create a major hindrance for meaning making in many biology classrooms (Mayaba et al.,2018; Prinsloo et al., 2018). The hindrance in MMOs and meaning making results from the fact that, the language of biology (made of the key content and various symbols) is unlike students' everyday languages (English, seSotho, isiZulu, or any one of South Africa's 11 official languages) that they bring into the T&L space. The language discrepancies often result in cognitive challenges during MMOs. Contrary to this, the social view of language is beneficial in that it does have the potential to encourage biology teacher educators to consciously use language as a mediatory tool for supporting MMOs, especially considering the complexity of the biology language as well (Ferreira, 2010). The conscious use of language by biology teacher educators may include involving their students in various social discourses such as whole-class discussions, group presentations, and verbal quizzes. Analogies and metaphors can be used to bridge students' everyday knowledge with scientific knowledge during MMOs.

Since this study was concerned with understanding the manifestation of MMOs in biology lectures, both the above-outlined perspectives will be acknowledged. Language in this study includes all the discourse tools (e.g. lecture-talks, worksheets, or course pack notes) that were used by the four biology teacher educators to promote MMOs in their teaching of biology to their undergraduate students. It was viewed as all the pedagogic resources whether verbal or non-verbal, that teacher educators used to help their pre-service teachers make meaning of biology content.

Lemke (1990) argues that language is an organised resource that is essential for meaning making. Language can help bring about the meaning of biology content through its semantic resources, one of which is 'discourse', (elaborated on in the sub-section 2.3.2. below). The semantics of language is primarily the study of meaning as it is conveyed through language. That is why Lemke (1990) views semantics as an interchangeable technical synonym for meaning. Thus, the semantics of language is an important factor in the teaching of biology because it not only institutes meanings but also helps pre-service teachers establish the relationships that exist between various concepts or topics. For pre-service teachers to effectively engage in the meaning making of biology, they first need to be able to express these relationships. Thus, the semantics of language enable them to bring about the meaning of the interconnectedness of biology concepts.

2.2.2. The discourse of biology

There has been a growing interest amongst science education scholars in studying the importance of spoken and written discourse, as well as the interactions that take place in different science classrooms (see Prinsloo & Harvey, 2018; Kelly, 2014; Osborne, 2010). Kelly (2014) says, 'discourse' can be regarded as a 'window' that can be used by biology teacher educators to access and re-arrange their students' thoughts about science during MMOs. The term 'discourse' in science education research refers to 'science talk', which can be understood as a social language that is used in science contexts. Thus, teaching biology entails teaching students how to 'talk' about biology during meaningful interactions of the lesson. 'Talking' about biology can be seen as an activity that allows students to use specialised and contextualised language through a variety of modalities such as reading, writing, problem-solving, analysing, and debating to mention a few. This relationship between discourse, language and meaning making is explored in more detail below.

2.2.3. The link between language, discourse and meaning making

Drawing from the arguments and explanations developed around the constructs of language, discourse and meaning making, it begins to create a picture that biology teaching should be an engaging experience that leads students into conversations about the scientific knowledge that they are learning about. These conversations are led through the medium of a language, which is used mainly to instruct, focus, and translate concepts in ways that students can better make meanings of the subject matter (Chun et al., 2022). On the other hand, discourse is important for relaying the scientific communication or meaning encrypted during lessons (Prinsloo and Harvey, 2018). Therefore, teacher educators must promote meaning making that engage students in conversations or interactions using both language and discourse. These may include reporting findings, explaining data, interpreting results, or creating a model to mention a few (Chun et al., 2022). Language is a mechanism that if used thoughtfully and deliberately by biology teacher educators can help to enhance their students' discourse and regularly provide them with opportunities to make connections and refine their ideas, thus extending their biology knowledge (Lemke,1990). This study suggests that language and discourse are integral components that

are not limited to the use of talking and doing science, but to stimulating students' active contributions to the meaning making processes of the lesson. The two pedagogical resources (being language and discourse) play extensive roles in the linguistic and conceptual development of students' biology knowledge, which are central features that result in meaning making.

2.3. Meaningful Learning Theory: Learning as construction of meaning

This section explores Ausubel and Novak's meaningful learning theory, which continues to yield valuable insights into the cognitive processes of learning in the existing literature, despite their long-standing history. Ausubel was the first author to propose the theory of meaningful learning in the 1960s in collaboration with his colleague Fitzgerald within the psychology field. While Ausubel is acknowledged as the primary originator of the theory, Novak made significant contributions to its development, particularly in the application of meaningful learning in educational settings. Novak in the early 2000s elaborated on a technique he named 'Concept Mapping' which characterises students' knowledge as a hierarchical structure of concepts and propositions, enabling students to connect new information to familiar ideas. Meaningful learning theory was deemed pivotal for underpinning this study, as it aimed to document how MMOs manifest in biology lectures, thus how students learn meaningfully became central.

Novak (2013) and Ausubel and Fitzgerald (1961) argue that the concept of meaningful learning explains learning experiences that are personally valued as rich and worthwhile by learners, in this case, students. Meaningful learning is often defined as cognitive changes and developments in the students' mental structures (see Sexton, 2020; Novak, 2013; Ausubel & Fitzgerald, 1961). Cognitive or mental structures are complex, rich, interconnected, multimodal representations of what people know (Onowugbeda et al.,2023; Novak 2013). For students to learn meaningfully, the knowledge being learned must not only comprise important concepts (Novak, 2002), but it must also be relevant to the existing prior knowledge that they already have (Ausubel & Fitzgerald, 1961). The situating and anchoring of new knowledge or experiences into students' relevant knowledge and mental structures is regarded as an important facilitative tool for meaningful learning (Sexton, 2020, Ausubel & Fitzgerald, 1961). For students to be able to construct meaning during learning, they need to be encouraged to interpret the new information with which they are presented (Ananda Kumar, 2023). The students' perspectives or ideas as interpreters extensively affect the meaning making process and talk becomes a central tool that they can use to articulate their thinking during MMOs. For example, Ananda Kumar (2023) proposes that for meaningful learning to occur, the new knowledge must challenge the students' previous mental structures and as a result develop new knowledge structures, a process Piaget (1964) termed 'accommodation'. However, when students are involved in meaning making segments where the new knowledge relates to the old knowledge, there may be little to no changes to the assimilation of existing mental structures. Novak (2013) says that it is only teaching experiences that challenge students' previous knowledge and allow new questions to arise that result in meaningful learning. That is why

previous research (e.g. Grove & Bretz, 2012; Novak 2002; Ausubel & Fitzgerald, 1961) showed that meaningful learning is likely to occur when students are involved in active, constructive, relational, intentional, and authentic teaching and learning activities.

Meaningful learning theory was seen to be in alignment with SCT, because they both emphasise learning, knowing, and thinking as being relational and context-dependent, as opposed to meaning being a 'transferrable entity' from the teacher educators' mind to the students' minds for it to be internalised. Within these theoretical perspectives, meaning making is regarded as both an individual and collective task, which involves meanings of the knowledge being negotiated through the various life experiences and prior knowledge that both the teacher educators and students bring into the lectures. Thus, it is through constant interactions with others that result in meaningful learning. Given that participants are engaged in not only exchanging ideas but in also modifying and revising their own individual understandings and/or meanings. Siry (2011) says that meaningful learning within the SCT perspective is extensively characterised by the teachers' acknowledgement of learners' prior knowledge as 'rich-resources' which they can draw upon during learning. Thus, when a biology teacher educator is seen in this study drawing on students' prior knowledge during a MMO they would be seen as trying to facilitate meaning making, a concept further elaborated upon below.

2.4. Defining Meaning making in the context of this study

Like language, numerous definitions exist for meaning making in education research and as a result, it has become a difficult term to understand. For example, Postman and Weingartner (1971) define meaning making as a process in which individuals in the learning environment are engaged in the act of interpreting, deciphering, and trying to understand or make sense of the knowledge presented to them about their already existing life events or experiences. Meaning making involves students reaffirming, retaining, revising, or replacing the components of their familiarising systems to develop useful and complex cognitive systems (Keagan, 2009). Whereas Novak (2002) terms meaning making as meaningful learning, which occurs when pre-service teachers integrate new knowledge into their previously learned knowledge as earlier stated. Scott and Mortimer (2012) say that meaning making can be regarded as sense-making, an activity that is characterised by learners talking about scientific ideas and building on their previous knowledge concerning the new knowledge presented during learning. Despite the clarity offered by the above definitions about what meaning making is, the problem associated with these definitions is that they tend to emphasise individualistic and cognitive processes at the expense of acknowledging the social and cultural dimensions inherent in knowledge construction. To address this limitation associated with the above definitions about meaning making, this study adopted a holistic perspective that integrates both individual and socio-cultural aspects of meaning making to align with the SCT which underpinned this study. Since this study explored how MMOs manifest in biology lectures, meaning making was therefore construed through the lens of the social semiotic perspective. Thus, aligning with Zittoun and Brinkmann's (2012) framework, which delineates

three levels of meaning making as a social activity. Before introducing the three levels of meaning making, firstly, an explanation of the semiotic perspective will be provided to rationalise its suitability for underpinning this study.

2.4.1. Meaning making within the social semiotic perspective

The social semiotic perspective is mainly concerned with meaning making and meaning makers. Thus, according to Hodge (2016), social semiotics can be said to be a study of how people create and construe meanings in social settings. Also, it can be said that the social semiotic lens is the study of meanings, communication, interpretations, and their significance (Kress, 2010). Taylor (2014) says that through this view, meaning is seen as a social and multimodal activity that is achieved collaboratively through discourse and multiple modes of language and/or talk (verbal, non-verbal, diagrammatic, or textual). Kress (2019) argues that language, discourse, and multimodality play an inseparable role within the social semiotic perspective, as they are all tools that facilitate meaning making within teaching and learning spaces.

Since this study is underpinned by the SCT (see section 2.1. above) it aligns with the social semiotic perspective. The study focuses on meaning as a social and multimodal activity that can be achieved using various modes of semiotic resources such as language (either verbal or non-verbal), and other scientific discourses that express meaning through all senses (Taylor, 2014). These semiotic modes or resources were deemed noteworthy as they can be used by teacher educators to promote MMOs in their lectures which may increase their students' understanding and/or participation which will be evidenced by various forms of student engagement with the concepts being taught or presented (Kress, 2019).

2.4.2. The three levels of meaning making

Sundermann et al. (2022) and Fraser (2015) argue that teacher educators at universities often wrongfully assume that merely explaining and transmitting knowledge of the subject, will result in pre-service teachers formulating meanings of the content presented. Unfortunately, that is not usually the case. According to Siry and Gorges (2020) similar to Amaral et al. (2007) meaning making is a complex intellectual and pedagogic task that requires planning, social interactions (through talk), and repertoire of teacher knowledge (see: sub-section 2.9 below), which is inclusive of the knowledge of the Pre-service teachers(e.g. their language, religion, cultural diversity and many other) to be carried out successfully. This view was also supported by Driver et al. (1994) as they stressed the importance of knowledge construction through the mental activity of learners within a social context. Thus, Zittoun and Brinkmann (2012) advise that teachers need to be familiar with how meanings are formulated by pre-service teachers to develop the skills required in promoting learning opportunities in their classrooms that will effectively engage their learners. According to Zittoun and Brinkmann (2012), there are essential three levels of meaning making that need to be considered by teachers and these are explained in more detail below.

Semantic level of meaning making

The semantic level of meaning has to do with an individual's comprehension of a language, symbols, and signs of the subject of specialisation (Kroeger,2023). The meaning making process takes place in a social setting, and it requires that students possess a conceptual understanding of their subject of specialisation, in this case, biology (Zittoun & Brinkmann, 2012). This understanding entails what makes up the subject, its language, social practices, and identity (Kroeger,2023). Within the semantic level of meaning making, teaching, and learning demands that students are involved in opportunities where they are socialised into the biology 'cultural' discourse and its methods of meaning, which all occur as they are talking and engaged in the process of meaning making (Zittoun & Brinkmann, 2012).

In this study, when students were given an opportunity to relate new biological concepts to their existing knowledge frameworks, such an instance was interpreted as the teacher educator involving them at the semantic level of meaning making. For example, if students were learning about the structure and function of cell organelles, they might use analogies such as a brick in the construction of a house or a flat in a prison. Evidence that such meaning making occurred was sought in students' verbal or written responses, their use of analogical reasoning, and their ability to connect organelles with cellular processes they had previously studied, such as photosynthesis or respiration. These observable forms of engagement, alongside lecturer prompts, would signal whether students are actively engaging with the manifesting MMO and possibly constructing meaning by integrating new information into their existing semantic networks, thereby deepening their comprehension and retention of biological concepts.

Pragmatic level of meaning making

The pragmatic level of meaning making has to do with the social activities that underpin a culture (Kroeger,2023). Culture is made up of social practices that are continuously undertaken and re-arranged, thus it is the teacher educators' role to ensure that students attain the ability to adequately participate in these social practices (Pacheco & Brown, 2024; Zittoun & Brinkmann, 2012). It is by participating in such cultural practices or apprenticeships that students develop the identity and gaze of their subject of specialisation (Lave & Wenger, 1991). Therefore, involving students in meaning-making that falls within the pragmatic level serves the purpose of encouraging them to feel like a part of a community of practice (Kroeger,2023). When students are engaged in the meaning making of the content of the subject, they can move from the peripheral positions of the community to attain a more central position through encountering complex meaning making discourses and engaging in dynamic as well as authentic interactions (Pacheco & Brown, 2024).

In a biology lecture, an example of pragmatic level of meaning making could be observed when students were seen engaged in opportunities which involved discussions or any activities that focused on the application of biological concepts in real-world contexts. For example, when students are asked to

analyse case studies or conduct experiments that simulate various biology-based scenarios. By engaging in such activities or opportunities, students would be prompted to not only understand the theoretical principles but also to consider how these principles are relevant and applicable in practical situations. Thus, engaging students in the pragmatic level of meaning making could enable them to recognise the value and use of biology knowledge beyond the classroom context.

Existential level of meaning making

Within the existentialism level of meaning making, teaching or lecturing considers the life experiences and knowledge that are brought in by students (Zittoun & Brinkmann, 2012; Scott et al., 2006). The learning experience requires that students draw from their life history, as they participate in authentic meaning making discourses (Wanselin et al., 2023). In this study when teacher educators engage their students in this level of meaning making, the students' initial perspectives might be put into question, reshaped, or completely altered. Zittoun (2011) argues that meaning making at this level can also be viewed as practices that engage the student emotionally, as they are required to use their life experiences. These experiences can be thought of and communicated within meaning making activities (Wanselin et al., 2023).

An example of the existential level of meaning making in a biology lecture could manifest during a discussion of the human evolution theory. During the discussion(s), students may explore questions such as the significance of human evolution theory in shaping their identities or the ethical considerations raised by evolutionary biology, such as the impact on conservation efforts or medical advancements. This level of meaning making goes beyond the mere acquisition of factual knowledge and probes into the deeper existential implications of biology concepts, fostering a more profound understanding and engagement with the subject matter. It is proposed that in this study for meaning making to happen, students need to be provided with an opportunity to engage with the content presented in various complex ways. The next section details what is meant by an opportunity in this study.

2.5. Defining an' opportunity' in the context of this study

The concept of 'opportunity' in the context of education is not generally conceptualised in the same light by different educational scholars in the field. There seems to be a general agreement on its importance and contribution to education based on various scholars' theoretical perspectives and research focuses. For example, Freire (1970) from a critical perspective, advocates for education to be a means of empowerment and liberation. Freire thus conceptualises 'opportunity' as the ability for learners to critically engage with content, question societal structures, and develop a sense of agency. This perspective means that opportunities for meaning making can be then captured as moments where students are encouraged to engage critically with the material, question assumptions, and connect biological concepts to real-world issues. This involves teacher educators creating a participatory

learning environment where students can feel empowered to contribute their various ideas and perspectives.

On the other hand, Darling-Hammond (2010) focusing on equity and access, stresses the need for high-quality teachers and equitable funding in the education sector. Darling-Hammond (2010) argues that 'opportunity' in education means providing all students with the resources needed to succeed, regardless of their socioeconomic status. In the context of this study, opportunities can be understood as ensuring that all students have access to the necessary resources needed to succeed. This includes not only physical resources like laboratory equipment and textbooks but also access to high-quality instruction that adapts to diverse learning needs.

In the mathematics education field, the concept of 'opportunities' is explored as opportunities to learn (OTL). According to Watson (2015), OTL is a concept that includes a variety of educational experiences, ranging from informal learning in everyday life to formal instruction within classrooms. Scholars active in this field (e.g. Darling-Hammond, 1997; Watson, 2015) have identified numerous orientations of OTL, including instructional quality, student engagement, sociocultural factors, and access to educational resources (Watson, 2015). Moreover, OTL can be distinguished based on its alignment with learners' needs, interests, and developmental stages (Sawyer, 2006). That is why Caroll (1963), a key contributor to the conceptual framework of OTL says that it is concerned with how students might construct knowledge when afforded an opportunity during an allocated time. For instance, according to Carroll (1963), if a student's task is to comprehend the concept of population density, OTL represents the time available for the student to grasp this concept. From Carroll's perspective, OTL is distinguished from the time a student needs to learn a concept, which is largely influenced by their aptitude in the subject area. While teachers can control the time allocated for student learning, they have little influence over the time required for learning. Carroll also contrasted OTL with the actual time students spend engaged in the learning process, often referred to as 'time-on-task' or engaged time. This latter variable is influenced by factors such as student perseverance, pedagogical quality, and the presence of learning opportunities. In Carroll's framework, the OTL represents the maximum potential for engaged time. On the other hand, Weingarden and Buchbinder (2023) framed OTL in terms of the relationship between content taught to the learner and content assessed by achievement tests, which brings about another variable to the concept. In the context of this study, OTL began to provide an understanding of the importance of ensuring that students have sufficient time to engage with complex biological concepts, the extent to which instruction is designed to promote deep understanding, and the availability of resources to support learning.

By integrating these various perspectives, the term 'opportunity' was therefore conceptualised as a favourable circumstance or situation that potentially allowed students to engage, critically reflect, learn, and construct meanings of biological concepts using the available resources and time given to them. In

other words, it was generally a 'chance' for students to ask questions, develop new skills, acquire new knowledge, and expand their understanding of a subject or concept during lectures. Since this study is interested in MMOs and how they manifest in biology lectures, the following sub-sections below seek to contextualise this construct for a better understanding of this study.

2.6. Conceptualisation of a meaning making opportunity (MMO) using Social Exchanges

Although the literature reviewed above revealed that there have been several studies that have explored meaning making, not many studies have paid attention to how opportunities that result in meaning making are manifested during T&L. Thus, literature concerning the concept of MMO does not exist as mentioned in Chapter 1. Mortimer and Scott (2003) state that "*If one is interested in how meaningful learning occurs in science classrooms, the best place to start is to examine the talk and other modes of communication…*" (p.10). This means that the key avenue for researchers to understand how meaning making transpires in science classrooms is to closely study the 'talk' that manifests and other modes such as visual representations, talk, writings, drawings, gestures, and actions, which Wertsch (1998) terms as social exchanges (SEs). These SEs became central in this study given the abstract nature of the biology concepts that would be covered in the various biology lectures. According to Wertsch (1998), SEs refer to the reciprocal interactions and communication between individuals within a social and cultural context, which play a critical role in cognitive development. Wertsch's (1998) work continues to be relevant in contemporary research because it builds on Vygotsky's theories and extends these ideas by focusing on practical tools that foster cognitive development in everyday T&L situations. These tools involve mediation, dialogicality, and collective remembering, which are stimulated by SEs. For example, Wertsch (2001) mentions that mediation refers to a teacher's use of cultural tools such as words, drawings and talk during social interactions. According to Wertsch, these SEs are not just passive instruments but are vital in actively shaping the way individuals think and interact with others and the world. On the other hand, the concept of dialogically and collective remembering involves dialoguing with others and internal dialogue, which are also facilitated by SEs such as talk, visual representations, writing, drawing, actions, and gestures. Thus, these SEs became critical tools in this study that could be used to document how MMOs manifest in the different biology lectures because they seem to trigger social interactions and stimulate cognitive development.

Talk, visual representations, and analogies are explored in greater detail below in this chapter as they are widely documented tools in literature and are critical components of the analytical framework while the other SEs such as actions and gestures as well as writing and/or drawing are explored in Chapter 4 where the analytical framework is developed.

2.6.1. Characterising talk in this study

Considering the extensive research existing within educational settings in general, various theories and perspectives, such as communicative approaches and triadic patterns of talk, have emerged to characterise the manifestation of talk in the classroom, and are expanded on below.

Dialogic discourse

The idea of dialogic discourse is a concept that was first extensively explored by Bakhtin (1981). In 2003, Scott and Mortimer expanded further on dialogic discourse and categorised it as interactive-dialogic discourses and interactive-authoritative discourses. For this research, dialogic discourse was regarded as an organised talk that permits sufficient space for students to freely interchange their responses with all the members present in the educational space (Barekat & Mohammadi, 2014). According to Barekat and Mohammadi (2014), each idea expressed during the meaning making activity necessitates a response from other participating members and must be building on other previously expressed ideas of others or oneself. Therefore, various meanings will emerge when students and their teacher educators are dialogically engaged in the meaning making process (Bansal, 2018). As proposed by Bhaktin (1981) dialogic discourse reinforces and promotes the participants' different values, voices, and perspectives, resulting in the biology discourse being integrally dialogic. Dialogic discourse allows teacher educators to develop content from their students' contributions while acknowledging their different ideas. Thus, making dialogic discourse an essential pedagogic practice that can be used to encourage discursive practices that support students' understanding and meaning making abilities (Rasku-Puttonen et al., 2012).

Non-dialogic discourse

Non-dialogic discourse in the context of this study was characterised by instances where teacher educators' ideas are the only ones that are promoted, and there is less engagement required from the students. Existing literature reveals that there are multiple definitions of non-dialogic interaction presented by different authors. Bakhtin (1981) views non-dialogic as authoritative discourse. Scott et al. (2006) and Mortimer and Scott (2003) argue that there are two different forms of non-dialogic discourse are present in science classrooms, namely, non-interactive-dialogic and non-interactive-authoritative. There seems to be a misconception that exists among many authors in this field of research, that tends to paint dialogic discourse as an ideal communicative approach for establishing meaning making in science T&L contexts. Authors such as Bansal (2018) and Scott et al. (2006) dispute this claim, and the authors propose that non-dialogic discursive patterns contribute significantly to shaping and organising students' meaning making schemas. This is because, through non-dialogic discursive patterns, science teachers can re-shape and re-focus their students' multiple ideas into ones that are consistent with the scientific worldviews through non-dialogic interactions. Non-dialogic interactions can also successfully contribute to meaning making, as there is reciprocity in the practice

of meaning making that occurs between students and their teachers through its use (e.g. Bansal, 2018; Bakhtin, 1981)

Although the above forms of talk provide insight and frameworks for capturing various forms of talk during learning, these communicative patterns as suggested by Bhaktin (1981) do not necessarily occur spontaneously. They result from interactions that occur between the teacher and students or amongst the students themselves, which will result in a triad best captured as IRF/E patterns. In this study, these interactions were deemed important in facilitating meaning making. Thus, talk in this study was captured in terms of the following SEs: (i) lecturer explanations (LE) which are known to play a central role in shaping instruction and learning (Rocksen, 2016). (ii) questions (Q) which Iurea (2015) says are not only crucial for stimulating students' thinking and engaging them in discussions but also foster receptivity to new knowledge, leading to increased eagerness to learn and problem-solving. (iii) feedback (FDBK) which Boud and Molloy (2012) see as information provided by teachers about their student's work and is inherently corrective in nature. All these variations of talk seemed to be essential in promoting MMOs that would result in various discursive patterns during learning. The rationale for this narrowed scope lies in the study's primary objective of this study which was to examine the manifesting MMOs in biology lectures using social exchanges. Consequently, the study placed more emphasis on the analysis of talk employed by teacher educators emphasising how their 'talk' shaped opportunities for social interaction. This intentional focus aimed to uncover how such talk may effectively facilitate the manifestation of MMOs in biology lectures.

Although 'talk' is central in stimulating social interactions in the classroom contexts, some studies have shown that given the abstract nature of the biology content, teacher educators need to integrate visual representations and/or analogies as means of promoting opportunities that will visually engage as well as concretise the content (see: Thyberg et al., 2024; Tippett, 2016), thus they are explained in the next sub-sections below.

2.6.2. Visual representations

Visual representations (VRs) are commonly defined as schematic diagrams or representations that are aimed at visually representing abstract scientific concepts that are usually not seen with the naked eye or are complex in nature (Kim & Jin, 2022; Brandstetter et al., 2017). Several studies have established the effectiveness of VRs in improving learning outcomes in biology. For example, research by Nichols (2018) found that students who received visual instruction performed better on comprehension tests compared to those who only received verbal instruction. That is why VRs are considered 'powerful' pedagogic devices that can be used by science teachers to transform and make information easily accessible to their students during learning (Tippett, 2016). Thyberg et al., (2024) assert that VRs can help students construct mental models for abstract biological concepts, therefore facilitating the integration of new information with prior knowledge. In this study, when a teacher educator used any form of VR alongside talk, they were seen as promoting an MMO in their lectures.

Despite the advantages linked to the use of VRs in biology education, it is important to note that numerous challenges and considerations have been reported by scholars in the field. One challenge is ensuring the accuracy of VR used, as inaccuracies can lead to learner misconceptions (Goff et al., 2017). Additionally, Erduran and Kaya (2018) suggest that it therefore essential for teachers to be mindful of the scientific correctness of the VRs that they use during their lessons. Thus, the use of VRs became an important SE that will be closely examined in the manifestation of MMOs in biology lectures.

Analogies as links to visual representations

Analogies like VRs are regarded as significant tools for teaching complex scientific knowledge (see Jaeger et al, 2016; Beger & Jäkel, 2015; Gee, 1978). According to Duit (1991), an analogy '*explicitly compares the structures of two domains and it indicates the identity of parts of structures*' (p.651). In other words, an analogy consists of a contrast between two unlike bases of knowledge, one which is familiar and one that is not. Suárez (2015) further says if biology teachers can masterfully create and express their analogies to their students, this can help their students overcome their misconceptions, clarify their thinking and channel schematic frameworks that can enable them to create a mental picture of the abstract concepts. For example, a biology teacher educator can use an analogy of bricks and walls to support or enhance their students' understanding of the conceptions of cells and tissues. The 3D form of bricks (representing cells) could be vividly seen and understood by students as to how a group of specialised cells can be regarded as the building blocks of tissues (represented by walls) in organisms. Analogies like VRs can also promote misconceptions if they are not clearly explained to students, thus teacher educators should pay attention to how they use analogies, thus it became another central SE to explore in the manifestation of MMOs in biology lectures.

According to Wertsch (1998) through these various SEs, learners can be supported to internalise external activities and dialogues, transforming them into internal cognitive processes. In this study, an MMO begin to be conceptualised as any occurrence or manifestation of two or more SEs, of which one is talk. Thus, the possible internalisation of these SEs can result in possible engagement and/or meaning making.

2.6.3. The relationship between SEs and Student Engagement

According to Godec et al. (2018), engaging students in science has been a central focus for many researchers in science education. This longstanding interest has led to diverse perspectives on the definitions and manifestations of engagement in science classrooms. Atkinson and Mason (2014) associate student engagement with the frequency of their participation in activities during teaching and learning. While Ainley and Ainley (2011) emphasise students' interest and enjoyment in science. This study is in alignment with the view offered by Fredricks et al. (2004) who conceptualised student engagement as a multidimensional activity made up of three main forms which involve: (i) affective-emotional engagement including attitudes, interest, sense of belonging and identification; (ii) cognitive engagement including persistence, willingness, motivation, and psychological investment to learn; and

(iii) behavioural engagement including participation in activities. The study adopted Fredricks et al. (2004)'s multidimensional framework to explore how students engage with and construct meanings during meaningful learning experiences. In this study, when students are seen raising their hands, laughing, asking questions, answering questions, critiquing or debating, taking notes, writing, drawing, demonstrating, reading, presenting and /or listening to the lecturer or their peers, all characterised students' emotional, behavioural and cognitive engagement during manifesting MMOs.

Pugh et al. (2017) argue that involving students in meaningful science activities is an important aspect of teaching the subject. This is because engagement is a tool that has the potential to:

- Foster the application of the scientific concepts taught as students answer questions during learning,
- Promote expansion of students' viewpoints (seeing events, objects, and issues through the lens of the science content)
- Encourage students' appreciation of the value of the taught content and establish its role in enriching their everyday experience.

To a certain extent, such learning experiences with such characteristics may be deemed ideal, especially in fostering student engagement during MMOs in science classrooms. To successfully engage students in science learning, Hadzigeorgiou (2016) suggests that teachers must use a repertoire of teaching and learning strategies that are aimed at helping them develop an understanding of the scientific ideas presented. Renninger and Bachrach (2015) suggest that it is crucial for science teachers to pay attention to both the intrinsic (internal) and/or extrinsic (external) factors that may either inhibit or promote student engagement when learning science. Renninger and Bachrach (2015) describe intrinsic factors as those issues or challenges within the individual involving psychological concepts such as motivation and interest. This means that when students are interested and motivated to learn, they are likely to be more engaged in the lesson and take up the manifesting opportunities during teaching and learning. But, when they lack interest, it is likely for them to not show any engagement regardless of how the content is presented.

On the other hand, extrinsic factors which are outside the individual often consider the context of learning, peers, family, and teacher support (Bempechat & Shernoff, 2012). Acknowledging the role played by these factors is crucial given that student engagement with the manifesting learning opportunities is a cyclical and dynamic process (Godec et al., 2018). In other words, when teacher educators engage their students in MMOs that are memorable, they are likely shaping their students' general dispositions toward further engagement. While on the other hand, the lack of MMOs or negative engagement experiences, are likely to have the opposite effect which may deter students from engaging completely in lessons (Lawson & Lawson, 2013). This goes to show that student engagement does not occur in a vacuum, it is often constrained by the type of opportunities occurring during teaching and

learning as well as agents or actors within a particular context of teaching and learning (Godec et al., 2018). The next section reviews learning preferences which aims to explain what prompts students to engage and learn during MMOs.

2.6.4. The relationship between SEs and learning preferences

According to Cuevas (2016), learning styles generally refer to individuals' preferences in their learning of concepts. This study adopts the concept of learning preferences rather than styles. These learning preferences encompass visual, auditory, reading and writing, and kinaesthetic modalities, aligned to the SEs to document the manifesting MMOs in the various biology lectures, thus they became important aspects. Neil Fleming was the originator of the Visual, Aural (Auditory), Read/Write and Kinaestathic (VARK) model in the late 1980s. This framework gained global attention among researchers, psychologists, educators and learners alike as it was deemed a useful tool for understanding and accommodating diverse learning preferences in various contexts. While that is the case, various studies (e.g. Gudnason, 2017; Coffield et al., 2004) have highlighted ongoing debates and critiques regarding the empirical validity and practical implications of learning styles in educational practice. These critiques, including those by Coffield et al. (2004), suggest that learning styles theories tend to oversimplify the complex cognitive processes involved in learning, reducing human cognition to a few discrete styles that may not fully capture individual learning experiences. Cuevas (2016) supports this argument, noting that learning styles often depict individuals as having fixed preferences for how they learn, despite evidence suggesting variability depending on context and developmental stage. Gudnason (2017) says that there are currently more than 71 models of learning styles some of which include (i) Kolb's Experiential Learning Theory: where learning is a cyclical process involving four stages: concrete experience, reflective observation, abstract conceptualisation, and active experimentation, (ii) Honey and Mumford's Learning Styles: Which builds upon Kolb's theory and involves the identification of four learning styles namely: Activist, Reflector, Theorist, and Pragmatist. (iii) Gardner (2015)'s Theory of Multiple Intelligences suggests that individuals may excel in different areas and have diverse learning preferences. (iv) Dual coding theory by Cuevas (2016) posits that there are two pathways to encode information into long-term memory, a visual pathway and a verbal pathway and many others.

In response to these developments, the debate continues over whether attention should shift from learning styles to learning approaches. Cuevas (2016) defines learning approaches as the strategies and methods individuals use to process information, shaped by personal, social, and cultural influences. Like learning styles, learning approaches also have faced some criticism. Coffield et al. (2004) argue that while learning approaches provide insights into how learners engage with tasks, questions persist about their practical implications for instructional planning and teaching strategies. Moussa (2015) argues that amidst these tensions, teachers and researchers should strike a balance between recognising diverse learner needs. Moussa (2015) further emphasises that effective pedagogy in science education necessitates a deep understanding of each learner's specific needs to design personalised instruction

that goes beyond broad classifications. While proponents of learning styles advocate for approaches like differentiated instruction, which modify teaching methods to suit individual preferences, the study adopted a learning preference approach. This decision stemmed from its focus on identifying and analysing the manifestation of MMOs rather than directly capturing students' cognitive processes during these opportunities. Therefore, the VARK model was regarded useful in providing key indicators for identifying and mapping various forms of students' engagements during manifesting MMOs, since the data collected in this study is only from the lecturers and not the students.

2.7. Possible barriers that could inhibit meaning making

Moje et al., (2001) say that meaning making can be hindered during complex scientific discourse. Unfortunately, this arises because teacher educators like their students bring various language and linguistic practices into their educational settings. These literacy and language activities are rooted in different discourses or ways of talking, doing, knowing, reading, and writing, which are developed and reproduced in various social and cultural practices or during discussions (Gee, 2000; Heath, 1983). This means that the knowledge sources that the biology discourse draws upon are not always limited to other sub-disciplinary fields of science but are sourced from other specific environments such as the students' homes, extramural activities, or through other community interactions. In the T&L context, challenges may arise due to disparities in the biology discourse employed by teacher educators during lectures and the discourse accessed by students based on their prior experiences or social backgrounds. This disjunction sometimes hinders students' ability to effectively construct and refine the meaning of the content presented, leading to potential difficulties or misconceptions in comprehension during MMOs. Arising from this challenge, ongoing debates among science scholars have emerged regarding the most effective ways in which teacher educators can assist their students in overcoming barriers related to scientific language and discourse issues, which can potentially hinder the process of meaning making during learning (see Gee 2010; Lemke 1990; Novak, 2012).

Matthews (2006) proposes that everyday language should not be introduced within science discourse, as it might be the root cause of difficulties in making critical differentiations when students attempt to engage in meaning making practices. On the other hand, other researchers (e.g. Brown & Spang, 2008; Dewey, 1902; Lemke, 1990) strongly suggest that it is important that students can make the links between their everyday discourse and the scientific discourse, and this study agrees with the latter view. This is considering that linking science language to that of students' everyday discourse establishes relevance, engagement, and interest among students. When lecturers link the two views of knowing, they usually offer their students an authentic experience of learning biology. Therefore, they can easily participate in the co-construction of the meaning of biology, as they will have the ability to engage in biology debates, contribute to discoveries, and participate in campaigns that might alleviate certain social ills, as well as lead to scientifically and technologically advanced societies (Aikenhead, 2006). Lecturers need to be able to fulfil their language mediatory roles in their teaching practices so that their

students can be actively involved in the co-construction of knowledge. Hence, students can be in a better position to make sense of biological phenomena, in their everyday lives (Kademian et al.,2017).

2.8. Teacher Knowledge constructs that influence MMOs

Since this study aimed to investigate how MMOs manifested in teacher educator lectures, they need to draw from different teacher knowledge bases. Teacher educators' roles in the promotion of MMOs are largely guided by the quality of their teacher knowledge domains. That is why researchers such as Scott (2000) and Scott and Mortimer (2012) suggest that to teach meaningfully, teachers need to be knowledgeable and draw from various knowledge bases. Wilson et al. (1987) state that knowledge bases are

"…the secret of an expert system's expertise, the body of understanding, knowledge, skills, and dispositions that a teacher needs to perform effectively in a given teaching situation" (p.106).

The above quote stresses that the expertise of a teacher is intricate. It encompasses not only the knowledge and skills directly related to the subject matter but also the broader understanding, skills, attitudes, and adaptability required to effectively navigate the complexities of a given teaching situation. This view is also supported by Fraser (2016) who says that teacher educators in HE institutions often draw from a diverse and rich knowledge base that encompasses subject-specific expertise, practical experiences, interdisciplinary connections to educational theory, and an awareness of the broader context in which learning occurs. There is a wide range of knowledge domains or models that have been documented in literature that are used by various lectures in various disciplines within the university context. Although that is the case, this study will only focus on the three central and **interrelated** knowledge domains which include (i) Pedagogical Content Knowledge (PCK), its sub-set (ii) Topic Specific Pedagogical Knowledge (TSPCK) (Mavhunga & Rollnick, 2013), and (iii) pedagogical reasoning. These three knowledge bases were particularly used because the teacher educators that participated in this study were training undergraduate pre-service teachers and according to Shulman (1976) PCK is a knowledge base that is unique to the teaching profession hence its appropriateness in this study. Since in this study the teacher educators were teaching specific topics, thus the TSPCK was also explored in sub-section 2.9.2. below. According to Fraser (2016), teaching is forever evolving because the nature of the T&L context is also dynamic, thus, they constantly need to think about their pedagogical reasoning in order to effectively teach their subjects of specialisations. Also, since Video Stimulated Interviews were carried out in this study, pedagogical reasoning was also explored alongside the other two teacher knowledge domains (see subsection 2.9.3 below). The subsections below will begin the exploration of PCK followed by TSPCK and finally pedagogical reasoning.

2.8.1. Pedagogical Content Knowledge (PCK)

Shulman (1987) explains Pedagogical Content Knowledge (PCK) as the missing paradigm in education research. Shulman (1986) introduced PCK as a specialised form of knowledge that integrates subject

matter expertise with an understanding of how to teach content effectively. Shulman (1987) points out that teachers need to possess more than just subject knowledge but need to also know how to transform knowledge into representations or 'chunks' that make it accessible to students. According to Shulman (1987), this knowledge transformation involves teachers selecting appropriate explanations, analogies, demonstrations, and instructional strategies that align with students' prior knowledge and learning needs. Hence, Shulman (1987) describe PCK as the blend of content and pedagogy, addressing both the 'what' and 'how' of teaching. Due to its significance in shaping effective teaching, PCK has been extensively studied across various educational fields to enhance teaching quality and distinguish the teaching profession from other disciplines. Simply put, PCK is a unique professional knowledge for teachers. To further conceptualise teacher knowledge, Shulman (1987) proposed the following categories of teacher knowledge, which include:

- **General pedagogical knowledge** (includes knowledge of central principles and strategies of classroom management and organisation which appear to be above subject matter)
- **Curriculum knowledge**, (knowledge about the programs and materials that are important 'tools of the trade' for effective teaching)
- **Pedagogical content knowledge** (knowledge that blends pedagogy and content which different teachers tailor differently to form part of their professional understanding)
- **Knowledge of learners and their characteristics** (knowledge about learners' prior knowledge, misconceptions, attitudes, values, etc.)
- **Knowledge of educational contexts** (knowledge about class, school, district, and governance operations as well as the functioning of communities and cultures; and
- **Knowledge of educational** ends, values, and purposes, as well as their historical and philosophical grounds.

After these initial advancements spear-headed by Lee Shulman, the field of PCK has witnessed remarkable progress, resulting in the development of numerous models that exist in literature. This progress has been propelled by continuous reflections, dialogue, and refinement of teaching practices among researchers in the PCK field, culminating in the emergence of the Refined Consensus Model (RCM) (Carlson et al. ,2019), as shown in Figure 2.1. below.

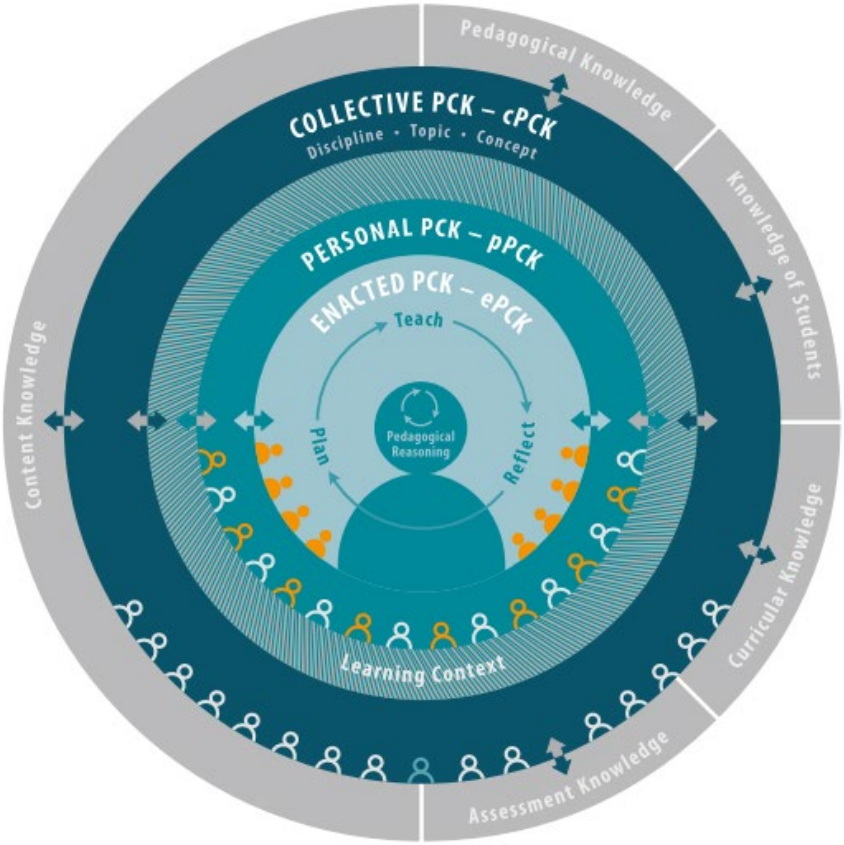


***Figure 2.1 Refined Consensus Model (Carlson* et al., 2019)**

As expressed by Carlson et al. (2019), the RCM outlines the intricate relationship that exists between experiences and knowledge shaping teachers' pedagogical practices and facilitating student learning activities as shown by Figure 2.1 above. A pivotal aspect of the RCM is its description of three distinct realms of PCK which are: personal PCK (pPCK), enacted PCK (ePCK), and collective PCK (cPCK) as depicted by Figure 2.1 above and further explained below.

Collective Pedagogical Content Knowledge (cPCK)

Carlson et al. (2019) explains that cPCK refers to the body of knowledge that is shared, accepted, and established within a particular teaching community. Such knowledge includes but is not limited to best practices, instructional strategies, and misconceptions commonly associated with a particular discipline. cPCK is knowledge that is often available publicly through research articles, textbooks, professional development programs, and teaching standards (Carlson et al., 2019). Additionally, Carlson et al. (2019) and Mavhunga (2019) highlight that cPCK serves as the foundation for personal and enacted PCK. It provides teachers with access to generalisable and research-based knowledge about teaching science. However, the transition from cPCK to personalised use requires critical reflection and adaptation to context (Carlson et al., 2019). Therefore, it becomes important that biology teacher educators must actively engage with cPCK to internalise and adapt it for their practice to be in a position of promoting the manifestation of MMOs in their lectures.

Personal Pedagogical Content Knowledge (pPCK)

According to Carlson et al. (2019) the pPCK is the individualised adaptation of cPCK by a teacher, which is informed by their experiences, beliefs, and understanding of their students. It is discipline, topic, and concept-specific but located in the teacher's personal cognition. Carlson et al. (2019) assert that pPCK is not merely a copy of cPCK but rather emphasises that it is a unique construct shaped by a teacher's teaching context, including the characteristics of their students, available resources, and cultural factors. Reflection is critical for transforming cPCK into pPCK (Carlson et al., 2019; Mavhunga, 2019). The dynamic nature of pPCK means that it evolves with experience, feedback, and ongoing learning. Thus, for the manifestation of MMOs in biology lectures, it is imperative that teacher educators evaluate how their general teaching principles align with their classroom realities.

Enacted Pedagogical Content Knowledge (ePCK)

ePCK refers to the observable manifestation of a teacher's PCK during instruction (Carlson et al., 2019; Mavhunga, 2019). It includes how teachers structure lessons, respond to student questions, and assess students' understanding of the presented content. It represents the intersection of planning, personal knowledge, and 'real-time' decision-making. According to Carlson et al. (2019), ePCK serves as the practical embodiment of pPCK, making it visible and measurable. ePCK is context-sensitive, meaning that teaching is influenced by situational and/or contextual factors such as classroom dynamics, student behaviour, and available time. Hence, for MMOs to manifest, biology teacher educators must recognise that teaching or lecturing is not a one-size-fits-all process. Given the diverse environments that biology lectures operate in which are characterised by varying contextual factors such as (i) **Learner needs and backgrounds** (students bring different prior knowledge, cultural experiences, learning preferences, and misconceptions to the classroom) (ii) **Curricular requirements** (education systems differ in terms of the prescribed curriculum, its sequencing, and its alignment with broader learning goals) (iii) **Classroom resources and constraints** (resource availability, including textbooks, technology, and teaching aids, significantly influences instructional strategies) (iv) **Sociocultural factors** (teaching is shaped by societal values, cultural norms, and language contexts, all of which impact how knowledge is constructed and shared).

So, the context-sensitive aspect of ePCK highlights that PCK in general is not static but rather progresses dynamically in response to the various contextual factors found in different teaching environments. By integrating this dimension, Carlson et al. (2019) provide a more holistic and practical understanding of effective teaching, where the interplay of knowledge, skills, and context is central to fostering meaningful learning experiences. This focus encourages educators in general to continuously adjust their pPCK during enactment, responding to unexpected challenges or opportunities in their various teaching contexts. ePCK highlights the adaptive expertise of teachers, demonstrating their ability to modify their plans and strategies during spontaneous teaching and learning activities. Observing ePCK is critical for teacher assessment and professional development, as it provides a

tangible record of instructional effectiveness. Hence, enacted PCK was a critical realm to explore since this study involved observing lecturers delivering different biology lectures (their ePCK) in various venues to diverse student groups, with the aim of documenting the manifesting MMOs that emerged during these lectures.

Interconnections Between cPCK, pPCK, and ePCK

The RCM model in Figure 2.1 above emphasises the dynamic and reciprocal relationships between the three PCK realms:

- From cPCK to pPCK: Teachers draw on the collective knowledge base to build their personalised understanding of teaching. This process requires teachers' ability to contextualise their instruction and content, where they adapt their general principles to their unique classroom settings.
- From pPCK to ePCK: Teachers' personal knowledge is transformed into practice during instruction. This transformation is iterative and influenced by feedback from students and self-reflection.
- From ePCK to cPCK: Observations of ePCK can contribute to the collective knowledge base when shared with the teaching community through research or professional collaboration.

Mavhunga (2019) highlights that these interconnections reflect the complexity of teaching and the importance of considering multiple perspectives when analysing PCK. The movement between these domains highlights the iterative nature of teacher and learning practices. Thus, highlighting the possibility that the manifestation of MMOs in biology lectures could also be a complex as well as spontaneous process rather than a pre-determined one.

From the RCM model depicted in Figure 2.1 above, it is important for the reader to note that each realm incorporates:

- **Discipline-specific PCK** which relates to the overall subject domain, e.g., biology, mathematics or chemistry.
- **Topic-specific PCK** which relates to the targeted knowledge for teaching particular topics, such as photosynthesis or genetics.
- **Concept-specific PCK** which speaks to the micro-level knowledge aimed at teaching specific concepts, such as DNA replication.

The RCM model depicted in Figure 4.1 above allows researchers and educators to focus on the granularity of teaching knowledge and its application in practice (Mavhunga, 2019). It also differentiates between knowledge that is shared and public (collective), individually held (personal), and observable in action (enacted). According to Carlson et al. (2019) these realms serve to contextualise the specialised professional knowledge held by varied science educators across numerous

educational settings, ranging from the broad knowledge commonly understood to the unique subset of knowledge individual teachers employ. Additionally, the model acknowledges that the broader professional knowledge bases serve as the foundation for teacher PCK, while the specific learning context in which a teacher operates significantly influences teaching and learning outcomes.

Science teacher educators' knowledge and effectiveness are central issues and major contributing factors for a sustainable and effective science education not only in South Africa, but globally. Ngware et al. (2014) argues that the way in which teachers use their teacher knowledge to plan and carry out their professional teaching responsibilities, can profoundly impact their students' ability to make meaning of their subject of specialisation. Unfortunately, there are some teacher educators who lack the teacher knowledge, and this usually negatively impact the way in which students engage in MMOs of the subject (Ngware et al.,2014). Teacher educators who lack teacher knowledge are often characterised by introducing new concepts to the students without explaining its origins, or significance and by not allowing them to freely express their ideas (Ngware et al.,2014). Thus, eliminating any possible opportunities of students being part and/or engaging in the meaning making processes, as a result student thus resort to 'cramming' without any basic understanding of the concepts being taught. In contrast, Fraser (2016) argues that teacher educators who have 'good' PCK are usually better equipped to creating numerous affordances that foster meaning making in their classrooms. The reason for this is teacher educators with 'good' PCK, generally are at a better position of transforming the content for their students thus making it more accessible during MMOs.

2.8.2. TSPCK

The four participating teacher educators were observed lecturing eight different biology topics which are outlined in greater details in Chapters 5,6,7 and 8. It was then deemed important to review a topic specific related PCK domains. Mavhunga and Rollnick (2013) argue that in teacher education training programs, there is still a wide use of generic PCK models. Mavhunga and Rollnick (2013) further argues that the extensive use of the generic PCK models may be the leading cause for the lack of conceptual understanding of the subject of specialisation among secondary science teachers (Rollnick et al., 2008) or the transmission approach that the 1st year professional science teachers take on when teaching science (Kind, 2009). Hence, Mavhunga and Rollnick (2013) developed a PCK model that is topic-specific which they termed as Topic specific Pedagogical Content Knowledge (TSPCK) as depicted by Figure 2.2 below.

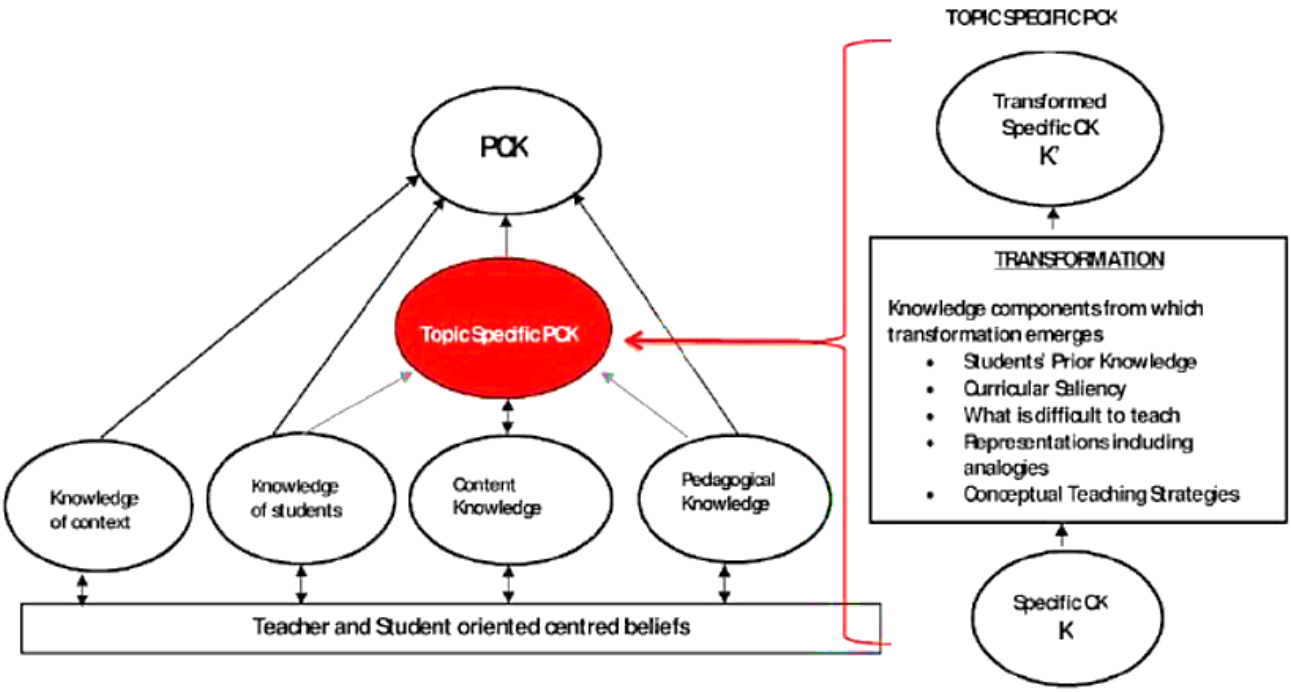


Figure2.2. TSPCK Model (Mavhunga &Rollnick,2013)

According to Mavhunga and Rollnick (2013) TSPCK is viewed *"as the understanding that provides the needed knowledge for transformation of content knowledge in a particular topic"* (p.2). Meaning that, for every topic, teachers need to be able to transform and make the knowledge of the topic accessible to their students, so that they can be able to understand it.

As shown by Figure 2.2 above, the TSPCK model consists of five different components which involve: (i)**Students' prior knowledge** which refers to general students' misconceptions and/or alternative conceptions, as well as correct knowledge about a certain content. (ii) **Curricular saliency** denotes to the learning of the certain topics, in relation to the curriculum. Within a topic, it is about understanding which concepts are most central and which are peripheral, the needed prior knowledge and the sequencing in teaching the concepts of the topic. (iii) **What is difficult to teach** refers to the teacher's ability to identify key concepts within a topic that are difficult to understand and not necessarily misconceptions, and it triggers awareness and possible interventions for teaching them. (iv) **Representations including analogies** refer to a variety of representations including illustrations, analogies, models, and examples, illustrations that are appropriate for teaching a particular topic. Lastly, (v) **Conceptual teaching strategies** refer to effective instruction strategies for addressing learner misconceptions, known areas of difficulty to learn, or known importance of concepts of the topic.

It is important to note that the above provided teacher knowledge domains serve as guidelines in teacher pedagogy. Their effectiveness in providing meaningful and engaging instruction that leads to student's conceptual development is largely dependent on the teacher's knowledge of the specific PCK or TSPCK constituents and their relationship with one another. However, this integration is made possible by

teachers' abilities to be able to think and reflect on their practice. Thus, the following sub-section reviews pedagogical reasoning, as the four biology teacher educators in this study participated in a Video Stimulated Recall Interview (VSRI) designed to elicit their pedagogical reasoning in relation to the various MMOs that emerged in their lecture, as well as the various factors that seem to affect their manifestation.

2.8.3. Pedagogical reasoning in the manifestation of meaning making opportunities in biology

Pedagogical reasoning refers to the cognitive and reflective processes educators use to transform subject matter knowledge into teachable content, enabling learners to construct meaningful understanding and foster student engagement (Loughran, 2019). Pedagogical reasoning involves understanding and unpacking teaching practices to reveal the knowledge and intentions guiding educators' decisions (Loughran (2019). Originating from Shulman's (1987) PCK model, pedagogical reasoning involves six key stages namely (i) comprehension, (ii) transformation, (iii) instruction, (iv) evaluation, (v)reflection, and (vi) new comprehension (Loughran et al., 2016; Loughran, 2019). In this study, these stages were deemed essential in providing a framework for teacher educators to critically analyse their teaching practices, adapting them to foster the manifestation of possible MMOs in their lectures. This is considering that, in the context of biology lectures, pedagogical reasoning is pivotal in bridging complex scientific concepts with students' prior knowledge and real-world experiences. Loughran (2019) argues that effective reasoning begins with **comprehension**, where biology teacher educators are assumed to thoroughly understand both the content and its relevance to students' needs.

This is followed by **transformation**, which involves the biology teacher educators having to select appropriate representations, examples, and strategies, such as analogies or visual aids, that make abstract biological concepts more accessible to their students thus facilitating the manifestation of MMOs during lectures (Loughran et al., 2016; Loughran, 2019). Instructional practices are then implemented, requiring teacher educators to facilitate the manifestation of interactive and engaging MMOS for students to process and possibly internalise information actively during lectures. The possibility of opportunities that lead to meaning making is further enhanced through **evaluation**, where teacher educators assess students' understanding and adjust their teaching approaches accordingly (Pilous et al., 2023; Loughran, 2019). **Reflection** on instructional efficacy allows teacher educators to identify areas for improvement, contributing to a cyclical process of possibly strengthened MMOs and adaptation. For example, a biology teacher educator lecturing on cell division might use interactive models or multimedia to illustrate mitosis and meiosis, linking these processes to familiar biological phenomena. Through reflective evaluation, the teacher educator can foster MMOs that are aimed at assessing whether students merely memorised the phases of mitosis or meiosis or developed a deeper conceptual understanding, informing their future teaching practices.

Generally, pedagogical reasoning can be viewed as a tool aimed at helping teacher educators to plan lectures that go beyond content delivery to ones that foster MMOs opportunities aimed at engaging students in meaning making. By reflecting on how students interact with the material, teacher educators can identify and address potential misconceptions and connect abstract ideas to tangible experiences that can result into the manifestation of engaging MMOs during lectures.

2.9. Conclusion

This chapter established the theoretical foundations for investigating MMOs in biology lectures, focusing on social exchanges (SEs- talk, visual representation, writing and drawing and gestures and actions), student engagement and learning preferences. Drawing on Sociocultural Theory and Meaningful Learning Theory, the study conceptualised MMOs as any socially mediated occurrences resulting from the manifestation of two or more SEs, of which one is talk. Thus, the possible internalisation of these SEs can enable students to engage actively during manifesting MMOs in the biology lectures.

Sociocultural Theory highlights the centrality of social interactions, language, and cultural tools in fostering MMOs, stressing how teacher-student and student-student dialogues create opportunities for constructing meaning making during lectures. Meaningful Learning Theory complements these by highlighting the integration of new knowledge with students' prior understanding, emphasising engagement as a key feature of meaningful learning. These theoretical constructs ground the study's central research question: ***How did biology teacher educators facilitate the manifestation of meaning making opportunities in their lectures?*** Since SEs will be used to document the manifesting MMOs that reveal the dynamic interplay of teacher strategies and students' possible responses.

The sub-research questions further refine the focus of the study. The first sub-question, ***what meaning making opportunities were facilitated by teacher educators in their lectures?*** is addressed through the lens of Sociocultural Theory and Zone of Proximal Development by identifying and documenting the SEs that enable or constrain MMOs. Teacher Knowledge as well as pedagogical reasoning also played a critical role in providing insights to this main research question. The second sub-question, ***what forms of student engagement (if any) were elicited in the biology lectures during the manifesting meaning making opportunities?*** was explored using Fredricks et al.'s (2004) multidimensional framework, which captures cognitive, affective, and behavioural engagement during MMOs. Finally, the third sub-question, ***what were the factors that promoted or hindered the manifestation of meaning making opportunities that were facilitated by teacher educators?*** was examined by analysing the sociocultural and contextual influences, including teacher knowledge, pedagogical reasoning which all seem to impact the effectiveness of MMOs.

By integrating SEs, and engagement within the above-mentioned theoretical frameworks, this set the stage for the development of the study's analytical lens which explained in greater depth in Chapter 4.

The analytical framework was used to systematically analyse the manifestation of MMOs in the various biology lectures, the forms of engagement they elicit, and the contextual factors that impact them. The next chapter will discuss the research design, and the methodology employed in this study.

Chapter 3

Research design and methodology

3.0 Introduction

Chapter 2 provided a comprehensive literature review that centred on the core problem investigated in this study. It contextualised the research within the frameworks of SCT and its key tenets, as well as meaningful learning theory perspectives, which served as theoretical underpinnings guiding this study. In this chapter, the research methodology and design are delineated, including an outline of the sample, procedures, ethical considerations, and issues of trustworthiness pertaining to the research instruments employed for data collection, alongside a detailed explanation of the data analysis approach.

3.1. Research paradigm

The paradigm guiding this study was based on the interpretivist framework, which emphasises qualitative analysis and the subjective understanding of reality through social constructions. König et al. (2024) define a paradigm as a theoretical framework that shapes individuals' understanding of reality and knowledge, thus forming the foundation for philosophically based scientific research. A paradigm provides essential components, such as hypotheses, research methods, epistemology, and ontology, hence being widely accepted by researchers (Junjie et al., 2022). According to Ignacio et al. (2024) epistemology is the study addressing how we come to know reality, while ontology refers to the study of the nature of reality.

In this study, I adopted the interpretivist paradigm, which emphasises human interest and the socially constructed nature of reality (Junjie et al., 2022). Interpretivist ontology takes a relativist view, suggesting that reality is subjective and shaped by social interactions, while epistemologically, knowledge is understood as being formed through human experience, interpretation, and interaction (Ni'mah et al.2024). Similarly, Treagust et al. (2014), argue that reality is accessed through social constructs, such as language and shared meanings. Some authors in the field (e.g. Creswell et al., 2011; (Junjie et al., 2022) further support these sentiments by proposing that meanings are constructed through the deconstruction and interpretation of the world, stressing the examination of subjective meanings within social and cultural contexts. William (2024) highlights that interpretivism seeks to explore the subjective realities individuals create, making this paradigm suitable for this study which aimed to explore how MMOs manifests in various biology lectures at SAX. The interpretivist paradigm was deemed appropriate for the grounding of this study, allowing for qualitative analysis and deeper insight into the socially constructed nature of knowledge (Junjie et al., 2022; Treagust et al. (2014); William, 2024). The interpretivist paradigm was also deemed essential in this study for exploring how MMOs

manifests in different biology lectures, drawing from William's (2024) assertion that this approach documents the complexity and multiplicity of truths.

Interpretivism has faced many critiques. English et al. (2024) argues that its relativist ontology, which values multiple perspectives equally, may lead to epistemological doubt and compromise scientific objectivity. Paudel (2024) adds that this relativism risks negativism, eroding the possibility of objective knowledge. The focus on understanding specific contexts rather than generalising findings may limit the applicability of results (Cohen et al., 2012). Paudel (2024) suggests that the subjective nature of interpretivism can introduce researcher bias, potentially skewing outcomes. Lastly, English et al. (2024) criticises interpretivism for not addressing the influence of ideology and politics, such as discrimination in education, in its analysis of social phenomena. To mitigate the above-mentioned critiques of the interpretivist paradigm in qualitative research, I followed some of Lincoln et al.'s (2024) proposed strategies to enhance data validity and reliability of this study such as:

- **Familiarisation with participants**: During the piloting and data collection stages, I managed to build trust with the participating lecturers, while ensuring that I did not consistently communicate with them to minimise any biases as suggested by Maxwell (2012)
- **Contextual Relevance**: According to Cohen et al. (2012) researchers should ensure that the study aligns with qualitative research contexts. For educational research, Cohen et al. (2012) suggest introducing relevant concepts and guiding participants to share examples, enhances the richness of data. During the Video Stimulated Recall interviews (VSRIs) I first asked the participants what they knew or understood about meaning making and meaning making opportunities which are central concepts of this study. Thereafter, these central concepts were explained to the lecturers in the context of the study before further asking the VSRI-related questions. When the lecturers provided superficial or ambiguous answers, they were probed further and asked to provide more insights into their responses.
- **Ensuring Honesty**: Hammersley (2013) emphasises the importance of establishing honest communication with the participants. To successfully do this, I encouraged the participants to respond to questions as honestly as possible by asking authentic questions and allowing enough space for their responses without any disturbances. During the VSRI, I also ensured that the environment was relaxed and used a conversational tone rather than an interrogative tone through the sessions. This conducive environment was established to allow the biology teacher educators to be as honest as possible in their responses without feeling any negative judgements directed towards them or their practices at any point.
- **Member Checking**: Cohen et al. (2012) explains member checking as 'participant validation', which is a qualitative research technique aimed at enhancing the accuracy and credibility of data, findings, and interpretations of a study. To ensure the accuracy and credibility of data in

this study, I invited four biology undergraduate lecturers to voluntarily participate in this study. Each of the biology lecturers was video and audio recorded teaching two different lectures consecutively to undergraduate students.

These strategies collectively enhanced the trustworthiness of the data sources (explained in greater detail in section 3.8. below) of this qualitative research that was grounded within the interpretivist framework.

3.2. Qualitative methodology

According to Creswell and Poth (2016) and Case and Light (2011), methodology can be regarded as a conceptual framework in which the research methods are situated. It can be said that methodology is a systematic approach that guides the research plan, resulting in the determination of the type of data to be collected and how it should be analysed (Bernard, 2017). Since this study investigated how MMOs manifest in biology lectures, a qualitative methodology was employed. This choice was based on the fact that qualitative methodology provides insights underlying the reasons, ideas, or attitudes about the problems that are being researched (Rahman, 2016). This is also supported by Hennink et al. (2020) who argue that a qualitative methodology often reveals trends in opinions and/or thoughts, as it tends to go deeper into the crux of the case that is being studied. This methodology was deemed suitable for this study because, one of the many benefits that are linked to it is that it involves multiple realities, which aligns with the adopted interpretivism paradigm (Hennink et al.,2020; Case & Light, 2011). The research approach not only provide descriptive details of the data but also adds a human voice to the findings (Creswell & Poth, 2016). Qualitative data was also regarded as suitable for this study because it uses various forms of data collection methods (Neumann, 2013). These includes, formal or informal interviews, video recordings, or audio recordings, which align with most of the data collection methods that were used to document the manifesting MMOs in the biology undergraduate lectures.

Despite the advantages of the use of qualitative methodology, Hennink et al. (2020) highlight that one of its disadvantages is that it does not yield numerical data, thus leading to issues related to generalisability, subjectivity, and ethical considerations to mention a few. That is why in this study, as earlier mentioned, the transcripts of the video recordings of the lectures (Appendices 12.1. A-D) and VSRIs (Appendices 12.2. A-D) were given to the participating lecturers and other colleagues to be validated, to bridge this gap associated with the use of a qualitative research approach.

3.3. Research Design

According to Sileyew (2019), research design is the framework that structures a study through a series of interconnected decisions, with the choice of research approach being central in determining how relevant data is gathered. This study adopted the case study research design. Cresswell (2013) a case

study approach is widely used in many fields, like sociology, education and psychology to mention a few. According to Yin (2017) a case study is considered both a research strategy and method. In this research design, a case can be an event, an entity, or an individual, based on the research questions guiding the study. Yin (2017) explains that there are two variants of a case study: the single case study and the multiple case study. Since this study explored four cases presented by four undergraduate biology lecturers, lecturing on various biology topics in their natural teaching environments, a multiple case study was deemed to be more appropriate. A multiple case study is a research methodology that allows for the exploration of a phenomenon through the examination of two or more cases, enabling a more comprehensive understanding of similarities and differences across contexts. A multiple case study allows for the analysis of data within each case and across different cases, providing a broader perspective that enhances the understanding of the phenomenon under investigation. Thus, in this study Chapters 5,6,7 and 8 all presented the single cases of the four biology lectures who were lecturing different topics to different groups of students and each chapter documented the broad spectrum of MMOs that manifested in each case.

According to Yin (2018), multiple case studies facilitate a comparative or cross-case analysis that helps in identifying patterns, commonalities, and distinctions among the cases, which in this study was done in Chapter 9. Queirós et al. (2017) explains that one of the advantages linked to the use of multiple case-study is their significant contribution to the literature as they reveal critical insights drawn from the observed differences and similarities of the case under observation. Also, Yin (2018) further highlights that another strength linked to the use of multiple cases is that it enhances the robustness of findings, leading to a more generalisable understanding of the subject matter. This view is also supported by (May et al., 2022) and Cresswell (2013) as they explain that the evidence generated from multiple case studies is considered strong and reliable, especially when results across cases are similar or when contrasting results are observed for expected reasons.

Despite their benefits, multiple case studies present challenges similar to any other research design, including being resource-intensive and time-consuming (Queirós et al., 2017). The extensive data collection and analysis required can be demanding, making this approach more suitable for research that aims to develop a strong empirical foundation. (Thomas, 2021) notes that while multiple case studies enhance representativeness, they may limit the depth of observation per case. To mitigate this limitation, this study employed a consistent, in-depth systematic coding process for each of the four cases, ensuring comprehensive analysis across all instances (Further elaborated upon on in sub-section 3.8.2 below).

3.4. Sampling

This study made use of both convenience and purposive sampling. Given that I was a student at SAX, convenience sampling was therefore used, because the participating biology lecturers were nearer and easier to recruit. Cresswell et al. (2011) propose that convenience sampling is one of the most common sampling strategies used in social sciences research. Opie (2014) states that convenience sampling is one of the most preferred sampling techniques because it is inexpensive, and usually readily available. May et al. (2022) argue that this sampling tool is sometimes not representative of the entire population. That is why in this research, convenience sampling was used in conjunction with purposive sampling. Purposive sampling is also one of the most widely used methods in educational research for the selection and identification of information-rich cases through the effective use of restricted resources (Patton, 2002; Thomas (2021). The purposive sampling process involves the identification and selection of individuals or groups that are particularly knowledgeable or have experience regarding the issue that is being researched (Cresswell et al., 2011). Thus, the four biology lecturers were purposively sampled for their knowledge of biology and lecturing experience for training students who are studying towards a Bachelor of Education (B.Ed.) degree at SAX. Hence, both convenience and purposive sampling were deemed suitable for this study as they appeared to supplement each other. Also, the sample was diverse in terms of gender, and this diversity was intentionally included to enhance the rigour, credibility, and trustworthiness of the study's findings (see Section 3.8).

3.4.1. Research Site and Participants

This study was conducted at a School of Education which is responsible for training pre-service teachers who were enrolled in a four-year program and were studying towards a B.Ed. degree. As depicted in Table 3.1 below, all four biology undergraduate lecturers were confirmed by the University to fulfil their lecturing positions, implying that they have obtained and reacted to critiques of their teaching ability. These four participating biology lecturers were given pseudonyms to protect their identities, and their background information is detailed in Table 3.1 below.

Table 3.1. The four biology lectures' summarised background and lecture information

Name of Lecturer	Age/Race/Experience	Qualification/s held	Teaching Philosophy	Class taught	Duration of the lectures/minutes		Number of PSTs taught	Content taught
					Lecture 1	Lecture 2		
Dr Chris	African male. About 55 years old. Teaching experience 30 years	B.Ed. BSc. Hons, M.Ed., PhD.	Inclusion, and Constructivism (particularly cognitive and social constructivism)	1st year Natural Sciences students	48	86	120	Introduction to cell biology
Dr Molly	African female. Age: about 55 years. Teaching Experience: 35 years	B.Ed., BSc Hons, MSc. Edu, PhD	PCK, and Constructivism (particularly cognitive and social constructivism)	3rd-year biology students (different group or cohort)	47	21	33 from a class of 86 in both lectures	Mitosis Animal tissues
Dr Moses	African male. About 50 years old. Teaching experience 25 years	B.Ed., BSc Hons, MSc. Edu, D.Ed.	PCK and constructivism	3rd-year biology students(different group or cohort)	90	45	64	Osmoregulation and excretion
Dr Ellen	African female. About 50 years old. Teaching experience 30 years.	BSc Hons, PGCE, MSc Edu, PhD	Constructivism and TSPCK used for planning	4th year biology students	90	45	60	Introduction to genetics and meiosis

*List of abbreviations used in the table: **NS**: Natural Science; **B.Ed.**: Bachelor of Education; **BSc Hons**: Bachelor of Science with Honours; **M.Ed**.: Masters in Education; **MSc**: Master of Science; **PhD**: Doctor of Philosophy; **PGCE**: Post Graduate Certificate in Education; **D.Ed**.; Doctor of Education

The data presented in Table 3.1 above indicates that all four participants were Africans between the ages of 50-55 and with more than 30 years of teaching experience, teaching various biology topics as depicted in Table 3.1 above. Notably, Dr Molly's lectures were of shorter duration compared to others, due to disruptions at SAX, which also impacted student attendance. A close examination of Table 3.1 shows that while the four biology lecturers shared certain teaching philosophies, such as social and cognitive constructivism, differences were also evident. Dr Chris drew from principles of inclusive education, while Dr Moses drew from Pedagogical Content Knowledge (PCK), which some scholars may dispute as being a distinct teaching and learning philosophy.

3.5. Data collection

According to May et al. (2022), data collection is a systematic procedure of gathering observations or measurements in research. In this study, I collected three forms of data namely, lecturer video recordings, PowerPoint Slides that were used in the lectures and VSRIs, to gain insights that would help me answer the research questions of this study. All these four forms of data collected are explained below.

3.5.1. Video recording of the lectures and fieldnotes

Prior to recording the lectures, participants were invited to voluntarily participate in the study. All prospective lecturers were emailed an information sheet detailing the overview of the research and the voluntary nature of their participation (see Appendix 12.5). Four biology lecturers demonstrated interest to participate in the study as earlier stated. As a result, I video recorded a total of 8 lectures, with a total of 472 minutes (approximately 8 hours) duration from the lectures observed. Video recordings according to Dempsey (2010) involve the act of capturing the actions of participants as they unfold. During the video recordings of the lectures, I directly observed and wrote some field notes so that whatever details were missed in the video recordings could be later revisited. Video recordings in this study were viewed as an appropriate data collection method as I captured the participating lecturers in their natural teaching environments. As a result, I was able to document how MMOs manifested using the developed analytical framework developed in Chapter 4 (consisting of SEs, student forms of engagement, learning styles and TSPCK components) and whether or not the lecturers managed to engage the students in their lectures. The information deduced from the video recordings shed light in answering all the study's research questions as it was considered as main source of data in this study.

The evidence gathered from the video recorded lectures was then used to prompt the VSRIs (explained in sub-section 3.5.3 below). Unfortunately, disadvantages that are linked with video recording is that the participants may experience discomfort of being constantly watched and the possible exposure of their student's identities without consent (Campbell et al., 2024; Opie, 2014). For this study, before the lectures began, two cameras were installed. One was positioned in front of the lecture venue, but

not too close to the lecturers to try and ensure that they had a sense of comfort in their teaching environments, which, ensured that their true teaching practices were reflected. The second camera was installed at the back of the lecture venue and was positioned in such a way that each and every action that the lecturer performed was captured. While I ensured that the students' identities were protected, I managed to capture their various forms of engagement (e.g. raising hands, pointing, laughing or other gestures) during the manifesting.

3.5.2. Collection of Prepared PowerPoint Presentations

After the classes were recorded, I asked the lecturers to provide me with their PowerPoint presentation slides (see examples depicted in Appendix 12.7) via email while some shared them using Google drive. I collected these slides to ensure that all the content in its different forms (text, pictorial, graphical, etc.,) could later be revisited and cross-referenced, during the data analysis phases. The video recorders were not always focused on the screen when I was recording the lectures resulting in compromised quality. PowerPoint slides were used to improve the quality of the supporting pictorial evidence to show the types of social exchange(s) that were emanating from them which were either initially not captured or poorly captured.

3.5.3. Video-Stimulated Recall Interviews (VSRIs)

. I scheduled the VSRIs based on the biology lecturers' availability and after confirmation, I sent each lecturer a unique Microsoft TEAMS link via email. As a result, I conducted a total of 4 (1 hour each) VSRI sessions with the biology lecturers on Microsoft TEAMS to gain deeper insights into their pedagogical reasoning and these interview sessions were recorded. According to Nguyen et al. (2013), VSRIs are a vital research instrument that involves the participants of the study being given a chance to watch video recordings of themselves aimed at sequencing their behaviour. During the VSRIs, Nguyen et al. (2013) explain that '*the participants will then be given a platform to critically reflect on their decision-making processes*' (p.1), so ideas about their awareness or lack thereof about certain practices is documented. Nguyen et al., (2013) highlight that one of the disadvantages associated with the use of VSRIs is its potential threat to the trustworthiness and credibility of a study. The reason is that participants can create 'explanations' about the prompted actions and their intentions. That is why in this study, the following steps were carried out to overcome the above-stated limitation linked to the use of VSRIs.

Step 1: Identification of areas of interest

Prior to the VSRI, the lecturers were given their lecture video recordings as previously mentioned. They were then asked to watch the videos and highlight any areas of interest that they would like to talk about. I also watched the two recordings for each lecturer in preparation for the VSRI and created a list of time stamps of all 'interesting' MMOs that manifested in their lectures to ensure that I did not prolong the sessions.

Step 2: Video playback

The second step was also carried out by the biology lecturers independently. All lecturers were asked to watch their video recorded lectures, as a means of recalling their lectures from their perspectives. According to Nguyen (2013), this is the most important phase of VSRIs, as it provides participants with an opportunity to reflect on their pedagogical choices, which enriches the interview session and data set in general. Throughout the VSRI sessions, before moving on to the segment that I had identified during the preparation phase, the lecturers were constantly asked whether there was anything else of interest that they would like to discuss. Once the VSRI session was completed, the recordings were downloaded and stored on a password-locked laptop.

3.6. The transcription processes

According to Whitney et al. (2024), the transcription process is a pivotal stage in qualitative research, especially if the data is to contribute to the production of scientific knowledge. In this study the transcription processes occurred in three steps for all data sets (recorded lecture videos and VSRIs) as explained in the sub-sections below to ensure data accuracy before it was analysed.

3.6.1 Transcription processes of the lecture video recordings

In transcribing the lecture video recordings of the study, I followed three essential steps which are explained in detail below.

Step 1: Video playback After watching each video recording three times and listening using earphones to avoid any distracting noises, I began checking my transcription process as detailed in step 2 below.

Step 2: Transcription

At this stage, I only transcribed the audio part of the videos. During this process, I listened to the video recording playbacks for 15 seconds then stopped to type the words verbatim. In this way, I could familiarise and analyse the data as I transcribed. There were instances where I struggled with hearing the lecturers' or students' spoken words which was mainly caused by (i) accents, (ii) the speaker being distant from the video recorder (causing the sound to be faint) and in some cases it was when the (ii) speakers' words overlapped with other sounds occurring in the teaching venue. In some cases, I was able to overcome these challenges by listening to the recording more than once or playing the video in delayed or slow motion. But there were cases where this method failed, and as a result, I labelled such segments in the transcript as inaudible. Whitney et al. (2024) mentions that accuracy is important in transcription because it provides information that sheds light on the questions that a study seeks to answer. After the completion of the audio transcription, I watched the video recordings again at least twice to ensure accurate transcription and to capture evidence of social exchanges as explained in step 3 below.

Step 3: Gathering evidence of social exchanges

There were instances where images were an essential part of the proceedings (e.g. SE) in support of the already transcribed words. In such occurrences, I had to pause the video recording at that particular segment then take a screenshot and paste it into the relevant section of the transcript (see **Appendices 12.1 A-D**). The screenshots included images of SEs such as gestures or actions, visual representation, etc. that were used by the participating lecturers to promote the manifestation of MMOs during lectures as exemplified by extract A in the later sections of this chapter.

3.7. Data analysis and processing

The lecture transcripts were analysed both deductively and inductively (see Appendices 12.1 A-D). According to Babbie (2013), a deductive approach is one where the researcher starts with an abstract, logical relationship among certain concepts and then proceeds towards more concrete empirical evidence that is being revealed by their data. On the other hand, an inductive approach requires that a scholar begins with an open mind that does not have any predetermined ideas that will be found (Azungah, 2018) because the main objective of this analysis is to generate new theories arising from the collected data. The deductive analysis of this study involves using the SEs that I outline in Chapter 2 and that I later explored in Chapter 4 as they form the analytical lens of this study. The SEs were mainly used to identify the manifesting MMOs in the various biology lectures. There was also an element of inductive analysis in the sense that the coding was not limited to the specific SEs that were outlined but rather was open to exploring other emerging exchanges that the lecturers used to promote the manifestation of MMOs in their lectures. This allowed me to see the variety within the types of SEs that the lecturers were using to promote various MMOs. For example, although all the lecturers were using visual representations (VRs) in their lectures, these were not necessarily the same (e.g. graphs, pictures, and many others). This became crucial information to document how lecturers used different variations of SEs that led to the manifestation of various MMOs in their lectures.

However, before the coding process could begin, I needed to find a way of systematically breaking the lectures into episodes, as explained in the below sub-section.

3.7.1. Breaking the lecture transcript into episodes

The first step that took place before coding began was the breaking down of the transcripts into episodes (see Appendices 12.1 A-D). To do this successfully, I adopted Buma and Nyamupangedengu's (2023) description of an episode. Buma and Nyamupangedengu's (2023) describe an episode as a teaching segment in which an identified concept is taught to completion. The segment is characterised by three parts: **an introduction**, **a body**, and **a conclusion**. The body was identified by words and/or statements or instructions such as: *Let's start*, *I want you to look at... and tell me*…and many others. The body could be a whole class discussion, students completing a worksheet or labelling a diagram, etc. The

conclusion, just like the introduction was marked by certain words and/or phrases such as *Now let's move…. Okay next …*and many others. To divide the transcripts into episodes, took several steps as outlined below.

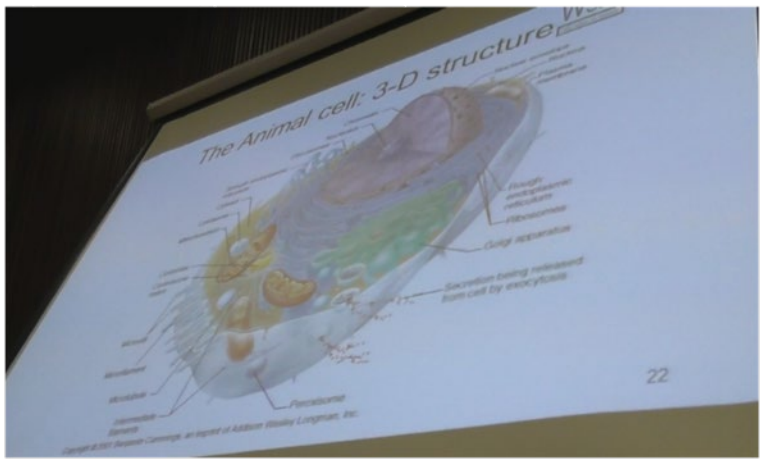
Step 1: I began by reading through the transcripts carefully to identify phrases and/or statements that would signify a beginning, body, and an end of an episode. This step was done twice to ascertain whether the identified beginnings and ends of episodes in a transcript were accurate.

Step 2: A body of each episode was characterised as event(s) that would have happened between the identified beginning and end of an episode. The body often involved the lecturer explaining the key concept (s) and students exploring it through the use of various SEs. Once the body of each episode was described, it marked the end of the process. Below, is an example of an episode showing how these phrases or statements which were used as signposts were identified.

An example extracted from Dr Chris's lecture showing how the introduction, body, and conclusion of an episode were mapped out

Extract A

Phrase signifying introduction

C: **Okay we will begin** by looking at the picture (Pointing), why is it a 3D picture? What makes it a 3D picture? A 3D picture of a cell? (Moves towards the PSTs) What makes it a 3D picture? And what does the D stand for? Yah! (Pointing at a PST who has their hand up) 
S1: I think that it shows the dimensions
C: **Alright**, which dimensions? **Phrase signifying a shift to the body**
S2: The 3 dimensions, like the front part, the side part, and the top parts.
C: Thank you, it shows the 3 dimensions. Which are the L lines?

Ss: (murmur their response)
C: The length, breadth, and height. So, we will have a diagram that shows the 3D structure, that shows the way things are. If you look at me you will see a 3D image of me because I have the height (Demonstrating with his hand), I have the breadth (still demonstrating using his hand) and probably some length (Continuing to demonstrate with his hand). Length (Demonstrating height) is this length?
Ss: No height (As they are laughing)
C: Oh, this is height, oh really thank you. Length? (While showing height)
Ss: Height!
C: Height (Demonstrating using hands) breadth, which one?
Ss: (Answers through demonstrating with their hands)
C: Yes, the shortest side. Length and which one is length? And this one is length (touches their stomach)?
Ss: (laugh)
C: I have a 3D structure. When you look at me your eyes see a 3D structure which is different from a 2D structure and the 2D structure has two dimensions. What are those two dimensions that are shown by a 2D?
Ss: Length and breadth **(Murmurs their response)**
C: Length and breadth (Repeating the PSTs' response) only and what is missing is the height. (Moves towards the slide and points at it) Okay, also the diagrams, like this one, the earlier one, the diagram of the cell, which is a typical diagram of a cell. (Moves towards the PSTs) The only thing we see there is length and breadth we can't see how thick it is and because of that it is a two-dimensional diagram. And you guys when you are in labs, when you are doing labs and when you are going to teach your learners you are going to teach them to represent 2D diagrams and I would like you to create, to make 2D diagrams. What does the D stand for?
Ss: Dimensions (all at once)
C: Dimensional. It's two-dimensional and three-dimensional. **So, next, we are going to be looking** at 2D and 3D diagrams and at the same time imagine how these are going to look like. So, the 3D structure of a cell what does it show us? You told me this, but I would like you to make a drawing of this, a 2D drawing please in the next five minutes. A 2D drawing of that 3D cell (Pointing at the 3D image of an animal cell on the slide).

Phrase signifying shift to the conclusion

Extract A above shows that during this episode, Dr Chris introduced the concept of *dimensions*, using the phrase ***"Okay we will begin by looking*** *..."* which marked the beginning of the episode. The body of episode 1 was marked by the phrase "***Alright..."*** which was interpreted to mark a shift from the introduction to the body. During the body of the episode, Dr Chris posed a question about dimensions which prompted a whole class discussion where students drew from their prior knowledge of the concepts. The conclusion of the episode was marked by "***So, next…"*** During this episode, Dr Chris recapped the key ideas discussed and instructed the students to make a drawing of a 2D animal cell. The duration of this episode was 7 minutes and 3 seconds. Further examples of how the lecture transcripts were analysed deductively using the SEs are explained in greater detail in Chapter 4, where the analytical framework is introduced (also see Appendix 12.1 A-D).

3.7.2. Transcription and analysis of the VSRIs

The transcription processes of the VSRIs involved all the three steps described earlier as described in section 3.7.1. above involving video playback, transcription and gathering of social exchanges were again applied. However, rather than just mapping out the social exchanges as done in step 2 in the above, I transcribed and categorised all the pedagogical reasons that were provided by the lecturers in terms of why they used certain SEs during their lectures some of which revealed some of the challenges and opportunities associated with the manifestation of some MMOs, that the TEs encountered in their lectures as exampled by Figure 3.1 below.

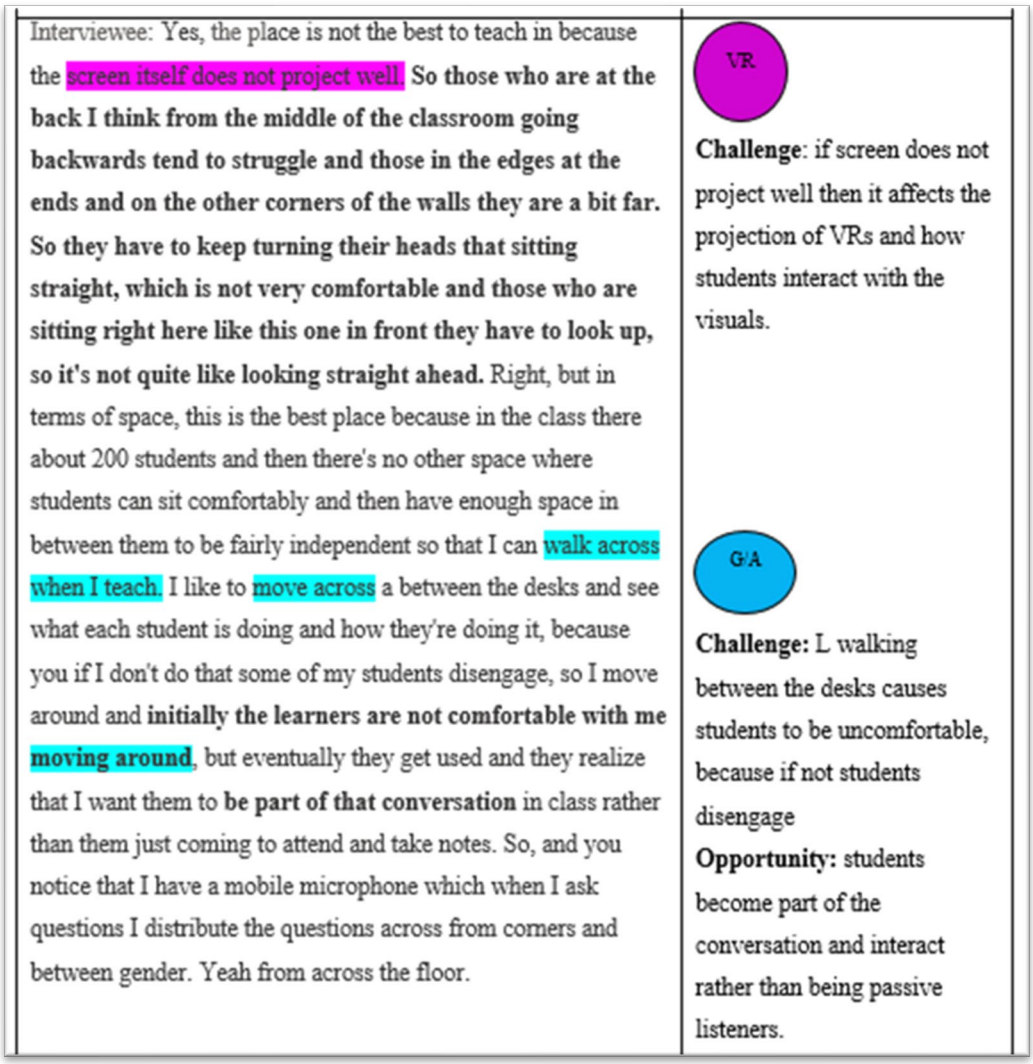


Figure 1 Showing the two challenges emerging from Dr Chris's VSRI

Figure 3.1 above illustrates the two challenges expressed by Dr Chris during the VSRI. These challenges were associated with the screen's poor projection, which affected the students' overall engagement with the projected visuals. Another challenge presented by Dr Chris was about the discomfort experienced by students when Dr Chris moved between the rows. According to Dr Chris, this approach was intentionally used to manifest MMOs that would actively engage students in the social interactions of the lecture.

To ensure that these various challenges and opportunities were accurately captured in this study, as earlier mentioned the lecturers were asked to share these experiences encountered in their lectures during the VSRIs. All these challenges and opportunities are further unpacked in the case-by-case analysis (see Chapters 5,6,7, & 8) of this study.

3.8. Rigour, Trustworthiness, and Credibility of Data Sources

Opie (2014) asserts that conducting a naturalistic inquiry is commonly not an easy task, as it can be influenced by the researcher's personal beliefs. Thus, qualitative research requires that multiple strategies are used when collecting data. Throughout the various phases of data collection, the researcher must always be concerned with issues of rigour which in turn can help improve the study's trustworthiness and credibility of data sources, as qualitative research is always open to questions. Authors active in the field (e.g. Enworo, 2023; Opie, 2019) believe that rigour equates to the trustworthiness and credibility of a study, hence the concepts are often hard to clearly define. According to Polit and Beck (2012), rigour refers to the state or quality of being precise, exact, or accurate. Enworo (2023) similar to Yin (1994) describes rigour as the strength of the research design and the suitability of the methods in answering the research questions.

Lincoln and Guba (1985) were the first authors to speak to the issue of rigour in their model of trustworthiness in qualitative research. Enworo (2023) suggests that trustworthiness denotes the authenticity and truthfulness of the findings of a qualitative inquiry. It can be a criterion that a reader can use to determine the level of confidence and trust they can have about the results of the study. On the other hand, Polit and Beck (2012) point out that credibility denotes the certainty of the data collected by the researcher. Trustworthiness also refers to the participants' opinions, representations, and interpretations of themselves by the inquirer. To ensure that I met the three criteria of 'truth' in this study, member checks, validation of the coding process and data trails (exampled by appendices 12.1-12.7) of the data sources were carried out in this study.

3.8.1. Member checks of data sources

As stated earlier, before the analysis process of the data began, the participants were given back the lecturer and VSRI transcriptions. During this process, the participants were asked to confirm, verify, and modify the transcribed excerpts of the information they provided, to strengthen the accuracy of the data (Opie, 2019). Thus, ensuring the trustworthiness and credibility of the findings of this study.

3.8.2. Reliability and validity of the coding process

In terms of transcription, to ensure the reliability and validity of the coding scheme, an independent person was engaged to validate the assigned codes. This individual was familiar with the coding

framework and worked to establish broad consensus with the researcher. Where discrepancies arose, discussions were held between the researcher and the independent coder to reach an agreement on the appropriate classification of the data.

For example, one key area of discrepancy was in the categorisation of lecturer talk, particularly in distinguishing between lecturer explanations and instructional talk. The independent coder initially identified some instances where lecturer explanation and instructional talk were coded using the same code. The independent coder disputed that these forms of talk cannot be the same code as they were different. Through discussion, a consensus was reached that only instances where the lecturer explicitly explained a biology concept would be coded as lecturer explanation, while instructional talk (such as providing directions or task-related guidance) would not be considered in this study as it appeared to mainly support or clarify the lecturer explanations in most cases. This process of validation ensured that the coding framework was applied consistently, enhancing the trustworthiness of the analysis.

3.8.3. Triangulation of data sources

Triangulation of data sources is the process of using numerous data sources to draw a valid conclusion (Opie, 2019). In this study, three forms of data were collected as mentioned earlier. The four data sources were carefully and thoroughly transcribed and triangulated to answer the research questions and to provide a comprehensive and insightful view to draw up possible conclusions for the study.

3.8.4. Collaborative platforms that were used to strengthen the rigour, trustworthiness, and credibility of the study

To further strengthen the rigour, trustworthiness, and credibility of the study across the doctoral journey, I actively engaged in multiple forums wherein various components or aspects of the thesis underwent rigorous critique, and diverse perspectives were solicited from various audience groups. These platforms involved participation in research weekends organised quarterly by the School of Education, weekly participation in the Postgraduate Research Authentic Conversations (PRAC), attendance at Southern African Association Research in Mathematics, Science, and Technology Education (SAARMSTE) conferences, and attending SAARMSTE research schools. Detailed descriptions of each of these platforms are further provided.

Presenting chapters at the Postgraduate Research Authentic Conversations (PRAC) and PhD. weekends

The two platforms were consistently used for presenting aspects of my work, particularly focusing on areas where I encountered challenges. One of these platforms was the PRAC, which comprised postgraduate students enrolled in the Mathematics, Science, and Technology division, alongside two

divisional lecturers who spearheaded the forum. The other platform was the Research Weekends, which was organised by the SAX. Both platforms required timely submission of presentations and corresponding chapters (one week in advance) to be submitted to the audience and critical readers, affording them ample time to engage and offer constructive feedback on the work submitted. The insights received from these platforms significantly contributed to the refinement of my study. For instance, during one presentation where I proposed using SEs, one lecturer, during the discussion session, mentioned her concerns about her not being sure how the MMOs would be documented in the study. She further indicated that it would be best that I clearly explain what I meant by an MMO in this study before attempting to use the SEs, as she sees a disconnect. Initially uncertain about this feedback, my supervisor who was present at the presentation later made me realise where the issue was. During the data analysis, this issue became crystallised when I realised that each manifesting MMO resulted from any two SEs, one of which was talk, which was how an MMO was later coined in this study as explained in Chapter 2. Consequently, these platforms played a pivotal role in enhancing the rigour, trustworthiness, and credibility of my study.

Annual SAARMSTE conferences and SAARMSTE research schools

Since commencing my Honours degree at SAX, I have maintained membership with SAARMSTE. My first presentation within this academic community occurred at Tshwane University of Technology in 2015. Subsequently, I have actively participated in numerous conferences and research schools associated with SAARMSTE, fostering connections with both local and international scholars whose invaluable feedback has significantly influenced my doctoral journey. For instance, during the research school hosted by the University of Pretoria in 2019, one of my assigned mentors scrutinised my proposal and identified a discrepancy between the initially proposed conceptual framework, which was Pedagogical Link-Making (PLM) and its misalignment with the study's objectives which were linked to MMOs. Upon deliberation with my supervisors, we concurred with the mentor's assessment and subsequently revised the framework, as documented in Chapter 2.

3.9. Ethical Considerations

The most essential elements that ensure the quality of research lie between ethical relations and its practices (Rule & John, 2011). Thus, conducting a study in an ethical method not only improves the quality, but enhances the rigour, credibility, and trustworthiness of that research. Hence, this study applied for ethical clearance before collecting the data from the participants. Babbie and Mouton (2001) state that the ethical standards of no harm to participants and voluntary participation must be well stated to the participants. Before collecting data, I applied for ethics clearance to the Ethics Committee in the Faculty of Humanities. After obtaining permission from the Faculty, I had to write a letter to the Head of School (see Appendix 12.4) requesting permission to conduct the study.

According to Babbie and Mouton (2007), participants must be provided with informed consent prior to taking part in a study. In this research, potential participants were first invited to volunteer, and those who agreed to take part were given information sheets (see Appendix 12.5) during the recruitment stage. These sheets outlined the purpose of the study, the procedures involved, and their rights as participants. Only after reading this information and voluntarily agreeing to participate were they asked to sign a consent form (see Appendix 12.6), before the scheduling of the VSRIs and any videotaping commenced. These documents emphasised participants' right to withdraw from the study at any time should they no longer wish to continue or feel uncomfortable. Furthermore, given that videotaping was part of the data collection process, participants' confidentiality and privacy were safeguarded throughout (Babbie & Mouton, 2001). Pseudonyms (Drs Ellen, Molly, Chris, and Moses) were used in reporting the findings to protect their identities and maintain privacy.

3.10. Conclusion

This chapter outlined the research methodology and design used in this study. It further provided an outline of the sample, procedures, ethical considerations, and issues of trustworthiness about the research instruments employed for data collection and overall study, alongside a detailed explanation of the data analysis approach. The next chapter explained the developments of the analytical framework that was used to analyse the data of this study.

Chapter 4

Development of the analytical framework

4.0 Introduction

The previous chapter detailed the methodology and research design used in this study. It further discusses the issues of trustworthiness and ethics as to how they were dealt with. Firstly, in this chapter, a description of the development of the analytical framework is presented. The constructs of SEs, student engagement and learning preferences are central to the development of this analytical framework for studying manifesting MMOs during biology lectures. Therefore, an explanation of the centrality of these concepts is provided. The chapter begins with a recap of the above key concepts. Secondly, an exploration of the concept of talk, a central aspect of MMOs and its sub-components, which involved explanations, feedback, and questions is also covered. Thirdly, other SEs like gestures, actions, writing, words and drawings are covered in greater depth. Fourthly, a detailed overview of the SEs, is also offered. Fifthly, the chapter provides exemplars of data analysis to show how the analytical framework was employed. Lastly, an explanation is provided about the relationship between the analytic framework and the research questions, illustrating how it guided the selection of relevant data to address these questions.

4.1. Recapping the central concepts of this study

As explained in Chapter 2, meaning making is the process of making sense of the knowledge that is presented. Whereas an MMO is defined as an occurrence that enables students a 'chance' to make sense of the knowledge being presented. A MMO in this study was said to be indicated by the co-manifestation of at least two SEs, with talk being one of them and different combinations resulting in different types of MMOs. These SEs were seen as tools that enabled biology lecturers to create occurrences for students to make sense of the knowledge that they were presenting. When students engaged with the manifesting SEs, it indicated an uptake of MMOs that could lead to potential learning. According to Vygotsky (1978), learning is the internalisation of SEs happening in a social plane during social interactions. In this context, the social plane is the teacher educators' biology lectures, where the MMOs were manifesting. Wertsch (1998) proposed seven SEs such as gestures, words, talk, writing, drawings, visual representations as well as actions, which all trigger various social interactions (such as dialogic interactions explained in Chapter 2) and hence MMOs that may foster engagement and possibly learning. These SEs are explained in greater detail in the next section as they were used to develop the analytical framework for the study.

4.2. Why Social Exchanges were used to develop the analytical framework for the study

As explained in Chapter 2, this study was situated within sociocultural theory and meaningful learning theory as its frameworks. The suitability of SEs in the development of the analytical framework of this study was justified as they collectively stimulate social interactions which are integral to meaning making (Mortimer et al., 2003; Wertsch,1998). According to Wertsch (1998), SEs are pivotal tools for stimulating and organising individual thinking, thus as earlier explained, their possible internalisation by the students can result in student engagement (Vygotsky,1978). When used 'effectively' by teachers they can facilitate a student's transition from the social to individual plane during learning. Wertsch (2009) argues that when studying meaning making in a teaching and learning context such as the classroom, one cannot ignore the close relationship between 'talking' and 'thinking' which are fundamental activities that are facilitated and mediated by cultural tools such as SEs and language as explained in Chapter 2.

Below, I describe each of the seven social exchanges listed above in section 4.1. in some detail. I begin by briefly recapping on talk and detailing its sub-component given that it is central to the manifestation of MMOs.

4.2.1. Talk

As explained in Chapter 2 (see section 2.6), talk is a dynamic concept that has been widely documented in research. However, in this study, talk was captured in terms of lecturer explanations (**LE**), questions (**Q**), and feedback **(FDBK**). These various forms of talk are explored in greater detail below.

Lecturer Explanations

Within this study's analytical framework, lecture explanation (LE) is defined as the purposeful communicative act by the lecturer during a lecture session aimed at clarifying, elaborating, and making accessible specific biological concepts (Lu et al.,2022). This includes not only verbal discourse but also the use of visual representations, analogies, and strategic references to students' prior knowledge embedded in interactive social exchanges (Kulgemeyer, 2020). Lecture explanations thus represent complex pedagogical moves that combine content delivery with scaffolding processes designed to foster student understanding (Röcken, 2016).

Analytically, lecturer explanations are treated as key MMOs because they constitute moments where the lecturer actively mediates the construction of scientific understanding. Research in cognition and education suggests that explanations play a central role in shaping instruction and learning (Röcken, 2016). Lecturer explanations assist students in integrating previous information with new content presented during meaning making activities in the lecture (Lu et al., 2022). Lecturer explanations are

essential in guiding, clarifying, consolidating, rectifying, and revising students' understanding of scientific ideas into coherent theories and principles.

Moreover, Kulgemeyer (2020) argues that explanations are not merely modes of content delivery but integral mechanisms of a dynamic and interactive learning environment. When lecturers incorporate everyday examples familiar to students or consolidate explanations with visual aids, they effectively foster meaning making. This approach is particularly important in diverse classrooms where linguistic and cultural factors influence how students engage with scientific concepts. Therefore, in this study, any instance in which a lecturer gives an instructional talk or explains a biological concept, whether through verbal explanation, visual tools, or by drawing from students' prior knowledge alongside other SES and was characterised as a MMO. This operationalisation positions lecture explanations at the core of the analytical framework, enabling systematic identification and examination of SEs that scaffold meaningful learning during biology lectures.

Questions

Based on the theoretical underpinning viewpoints of this study, questions play a pivotal role in the manifestation of MMOs, as they seem to guide learners in constructing knowledge through dialogue and interaction.

In science education literature, various types of questions are commonly identified and can be used to promote inquiry and critical thinking among students (Koć-Januchta et al., 2020; Nur et al, 2023). The specific classifications of these questions vary, but generally, they can be grouped into eleven broad categories and are summarised as (i) **Open-Ended Questions**: Requires students to provide detailed and various responses, allowing students to express their understanding more comprehensively. (ii) **Closed-Ended Questions**: Require predetermined answers or a brief response, such as '*yes*' or '*no*' (iii) **Probing Questions**: Require teachers to delve deeper into a student's response, encouraging them to provide more details on their thinking. (iv) **Conceptual Questions**: Explores students' understanding of important concepts, principles, theories, and laws. (v) **Hypothetical Questions**: Involves presenting speculative or imaginary scenarios that prompt students to consider various potential outcomes. (vi) **Inquiry-Based Questions**: Involve students in the process of scientific inquiry as they enable them to discover, explore, and investigate. (vii) **Problem-Solving Questions**: Require students to apply their existing or prior knowledge and skills to solve science-related hypothetical or real problems. (viii) **Evaluative Questions**: Enable students to critique and assess scientific information. (ix) **Reflective Questions:** Enable students to reflect on their ideas, understandings, or general learning experiences. (x) **Collaborative Questions**: Enable group discussions that foster teamwork and the sharing of different perspectives. (xi) **Rhetorical Questions**: In this type of questioning, students are not expected to answer; the questions function as statements, reflecting the teacher's view and assuming agreement from all.

Sriratanaviriyakul et al. (2019) argue that questions in general play a pivotal role in driving discussions or interactions that engage science students, offering them a platform to process knowledge actively rather than passively receiving it. In addition to that, Sriratanaviriyakul et al. (2019) indicate that questions serve a crucial role in prompting students to think critically and encourage them to share their ideas within the social plane. Iurea (2015) emphasises that stimulating students' thinking through diverse questions not only engages them in discussions but also fosters receptivity to new knowledge, leading to increased eagerness to problem-solving. This active engagement aids in organising knowledge within students' cognitive frameworks (personal planes), facilitating a more profound understanding of the content. During data analysis, I focused on three types of questions involving open-ended, closed-ended, and rhetorical. The reason for this decision was based on Sriratanaviriyakul et al.'s (2019) argument that there are essentially three fundamental questioning styles that promote conceptual learning in science education. Sriratanaviriyakul et al. (2019) state that these ten categories overlap during teaching and learning. Science teachers often blend elements from multiple question types to create an engaging learning environment. In this study, the use of any of the above three types of questions (open-ended, closed, and rhetorical) by a biology lecturer alongside any other SE(s) was considered a manifestation of a MMO.

According to Finn and Schrodt (2016), various question types can result in two types of discussions which involve teacher-led or lecturer-led discussions and peer discussions. Discussions are particularly used in high enrolment courses to complement lectures. These two types of discussions are elaborated on next.

Lecturer led discussions

Lehesvuori et al. (2013) suggest that, despite lecturer-led discussions being predominantly teacher-centred in nature, they are important in offering students opportunities to collaboratively share ideas in a guided manner. The central responsibility of the lecturer in such discussions is to facilitate and mediate the exploration of key concepts during the discussions. That is why Grace (2009) advocates for the deliberate facilitation of lecturer-led discussions that elicit meaningful interactions among students, whilst stressing the importance of teachers posing various questions that gauge various levels of students' understanding, such as knowledge, application, analysis, and comprehension. Therefore, in the context of this study, when a lecturer is observed leading discussions using various questions alongside any other SE(s), such an occurrence again signalled a manifestation of a MMO. Given that Nur et al., (2023) argue that questions asked by science teachers can result in discussions that can be fruitful in fostering meaning making among students as they allow them to develop conceptual frameworks for understanding concepts better during learning.

Peer discussions

Unlike lecturer-led discussions, peer discussions are largely student-centered in nature. Tullis and Goldstone (2020) say that peer discussions are beneficial to students' learning, as they improve their theoretical and conceptual understanding of the content learned. Peer discussions play a role in shaping and developing students' problem-solving skills as they 'try out' or test their ideas on their peers. Moreover, as students participate in meaningful peer discussions, they are forced to go beyond just plugging in formulas or memorising terms. Taking into consideration that peer discussions provide students with opportunities to learn how to explain their thinking processes and actions using their own words. That is why peer discussions have been advocated as one of the best instructional strategies for fostering meaningful learning in science classrooms (Newbury & Heiner, 2012; Tullis & Goldstone, 2020). Like lecturer-led discussions, the manifestation of peer discussions prompted by questions in addition to any other SE(s) signalled a MMO in this study.

Feedback

The historical roots of feedback in science education trace back to Ramaprasad (1983), who initially defined it as information regarding the disparity between students' current performance levels and their reference standards. Hattie and Timperley (2007) further elaborate that teacher feedback is specific information provided by educators concerning a student's comprehension or performance, to minimise gaps between current and desired levels. Similarly, Boud and Molloy (2012) regard feedback as instructional information delivered by teachers to students regarding their work, primarily focused on rectifying and addressing observable or identifiable deficiencies. In contrast, Kerr (2017) argues that verbal feedback constitutes a distinct form of communication aimed at bridging the knowledge gap displayed by students during T&L. Kerr (2017) emphasises the importance of this distinction, highlighting how verbal feedback differs from other types of communication, such as task instructions or general behavioural comments. Verbal feedback, according to Kerr (2017), involves interactive exchanges between learners and teachers, fostering questioning and exploration to facilitate learning gains. Thus, this study adopted Kerr's (2017) view of the concept of feedback, given that during lectures, teacher educators constantly engage in talk or interactive exchanges with their students during MMOs. As earlier explained this definition of verbal feedback aligns with the sociocultural perspective that underpins this study, which asserts that learning happens during social interactions. In this study, when a lecturer provided verbal feedback alongside any other SE (s), that instance marked the manifestation of a MMO. Kerr (2017) argue that students perceive verbal feedback as part of their learning and rely on it to enhance their learning. Through verbal feedback, learners engage in revision and re-conceptualisation of concepts, recognising a gap between their goals and performance, resulting in increased engagement and/or intrinsic motivation (Kerr, 2017).

4.2.2 Gestures

Hong and Yang (2017) say that generally when people talk, they gesture as a way of emphasising what they are trying to say. Gestures can manifest consciously or unconsciously during T&L. Bezemer and Kress (2020) view gestures as intentional signals and movements of body parts that are important in communicating ideas without words. Radford (2009) says that some of the common gestures that occur in science classrooms involve pointing, using fingers to indicate amount or shape, and waving to mention a few. Taylor (2014) asserts that a gesture is a central feature of language that promotes meaningful science T&L of new information, as it often reflects an individual's underlying experiences and knowledge. Radford (2009) argues that gestures are not merely hints for interpreting an individual's mental state during meaning making but they are rather authentic components of thinking that drive meanings. So, when a lecturer was seen making use of gestures in conjunction with any form of talk during their lecture as a way of making their students comprehend certain concepts, such an instance again marked the manifestation of a MMO in this study.

4.2.3. Actions

Hostetter et al., (2020) explain that gestures are schematic in nature and are used to show the particulars of a movement, whereas actions highlight the overarching goal of the movement itself. Hostetter et al., (2020) suggest that actions are purposeful movements aimed at achieving specific goals, while gestures are movements used to communicate meaning or information, often accompanying speech or serving as standalone non-verbal communication. According to the authors, gestures are more flexible and can highlight specific aspects of a movement pattern or concept, while actions are constrained by physical parameters and are directed towards achieving a particular outcome during learning.

Actions like gestures can be effectively used in science classrooms during demonstrations to explain abstract biology concepts (Thörne & Gericke, 2013; Taylor, 2014). Actions like gestures play a pivotal role in capturing students' motivation and interest, thus fostering interactive and memorable learning experiences. Moreover, actions serve to bridge the gap between biology content and students' daily experiences. Taylor (2014) says that when science teachers use various actions to demonstrate how biological principles operate in the real world, students can better grasp complex ideas and phenomena. When a lecturer was seen making use of actions (like pointing at a slide to focus students on certain images or concepts or demonstrating processes or structures using their fingers or hands) in conjunction with any form of talk during their lecture as a way of making their students comprehend certain concepts, such an instance again indicated the manifestation of a MMO in this study.

4.2.4. Writing

Barry et al. (2019) say that writing serves as a form of discourse, where participants may use texts or symbols to capture, communicate and exchange ideas during learning. According to Drew et al.

(2020), students' writing can be described as a discursive tool that captures their thinking processes as they engage in meaningful learning. During discussions, teachers often write students' responses on the board. According to Barry et al. (2019) these written records not only provide evidence of students' thinking but are central in supporting them as they respond to and revise their ideas throughout the learning process. That is why in science classrooms, writing done by both teacher educators and students extends beyond a mere tool for exchanging scientific ideas. Writing like discussions are key in creating collaborative spaces during learning, thus its manifestation in this study in addition to any form of talk and SE(s) marked as a MMO. Barry et al. (2019) further argue that writing activities like discussions in science classrooms contribute to the development of a conducive environment for shaping thought and ultimately for fostering conversations. For instance, when a lecturer incorporates a writing activity or displays a written prompt, it serves as a stimulus for eliciting both new and prior ideas among students which can be discussed during interactions. That is why Ellison et al. (2020,) state that:

"*Writing in science is not only for communicating with others; it is also a tool for learning that supports scientists and students alike in clarifying thinking, synthesizing ideas, and coming to conclusions." (p13)*

The above-captured quote reinforces the idea that writing in science classrooms is a dynamic and essential aspect of the learning process in science education.

4.2.5. Words

Taylor (2014) explains that words, much like writing, serve to define, elaborate, and create ideas. Lemke (1990) explains that words are crucial components of language, whether written or spoken, making them indispensable social tools for formulating meanings in T&L contexts. Liamputtong (2013) also supports this notion, asserting that words in science education facilitate communication, support cognitive development, and enhance engagement as well as overall understanding of scientific concepts. As earlier stated, Vygotsky (1978) theorised that language is a fundamental cultural tool that mediates cognitive development, with individuals using words through social interactions to construct shared meanings and internalise knowledge during learning. As discussed in Chapter 2, Wertsch (1998) built upon Vygotsky's ideas, highlighting the mediational role of language in cognitive processes and the significance of dialogicality in human thought or thinking. Grossen and Muller Mirza (2020) explain the concept of dialogicality of words as a tool for capturing the variations and multiple layers of communicative situations that reveal how meaning making processes are inherently contextual and interactional in their nature. Similarly, Bakhtin's theory of dialogism highlights the role of words in social interactions, arguing that meaning is co-constructed through dialogue, where words embody the voices of multiple speakers and contexts (Bakhtin, 1981). This perspective stresses the dynamic and interactive nature of language in meaning making. Thus, when teacher educators use written and spoken words in this study, such an occurrence signalled a manifestation of an MMO.

4.2.6. Drawings

Drawing, within the context of biology education, is increasingly regarded as a powerful tool for enhancing student learning and engagement (see Fan 2015; Nugraha, 2018; Quillin & Thomas, 2015). This is particularly because many biological concepts involve abstract, microscopic, or complex processes that are not readily observable. Quillin and Thomas (2015) define drawing as a dynamic process that involves constructing and interpreting visual models to represent biological concepts. This conceptualization of drawing extends beyond mere artistic skill; it is viewed as a cognitive tool that aids students in visualising, organising, and processing biological information (Nugraha, 2018; Quillin & Thomas, 2015).

Fan (2015) emphasises that drawing serves as an active learning strategy that enhances scientific thinking. When students engage in drawing, they are required to interpret information, integrate knowledge, and produce a visual output that reflects their understanding. This process activates cognitive pathways that support comprehension and retention (Nugraha, 2018). Unlike passive learning methods, drawing fosters deeper cognitive engagement, allowing students to reconstruct knowledge in a meaningful way (Fan, 2015).

Similarly, Nugraha (2018) highlights the use of drawing as an alternative assessment tool in biology education. Traditional assessments often rely on verbal or written responses, which may not fully capture students' understanding of complex biological concepts. Drawing assessments, however, require students to visually demonstrate their comprehension, revealing both their strengths and misconceptions (Nugraha, 2018). By analysing students' drawings, biology teacher educators can gain valuable insights into their thought processes and identify areas requiring further clarification. Thus, in instances where a lecturer incorporated drawing or encouraged students to draw alongside any form of talk, such moments or instances signified the manifestation of a MMO.

4.2.7. Visual representations

As explained in Chapter 2, visual representations (VRs) are commonly defined as schematic diagrams or illustrations designed to visually depict abstract scientific concepts that are either invisible to the naked eye or inherently complex in nature (Kim & Jin, 2022; Brandstetter et al., 2017). Analogies, charts, diagrams, text on slides and many other aids were regarded as visual representations in the study. Visual representations are important pedagogical devices that science teachers use to concretise the abstract scientific ideas spoken about during meaning making. Thus, when a lecturer used a VR in conjunction with any form of talk, such an occurrence characterised the manifestation of a MMO.

4.3. Development of the analytical framework

The seven SEs described in the preceding section were used to develop the analytical framework. The development of the analytical framework was not a straightforward process but emerged from trial and error during the coding processes explained below. During the coding processes using the SEs, three

major challenges were encountered which were (i) related to differentiating some codes (ii) mapping and differentiating the emerging SES and (iii) capturing students' engagement and the complexity of the manifesting MMOs. The three challenges are explained in greater detail below.

4.3.1. Challenge 1: Differentiating some SEs apart during coding

Once the coding process began, one of the major challenges encountered was with regard to distinguishing some of the SE codes apart. It became difficult to separate gestures from actions. For example, when a lecturer made use of a demonstration using a bodily gesture, it could also be interpreted as an action. As a result, I adopted Radford's (2009) definition of a gesture as a bodily action, thus combining these two codes. While trying to capture actions and/or gestures on the lecture transcripts in isolation from the actual video recordings, I realised that some of the lecturer's actions were not captured initially. As a result, the video recordings of the lectures were re-watched numerous times again to capture and code all these that were identifiers of the manifesting MMOs in this study.

During the coding process, I struggled to distinguish words from talk and writing, given that words are building blocks of talk and written words. Consequently, I again then categorised all the spoken words as talk while I classified the written words as writing. As a result, instead of the seven SEs proposed by Wertsch, I revised them to four SEs in this study as a means of being able to effectively document the manifesting MMOs in the various biology lectures as displayed in Table 4.1 below.

Table 4.1 Initial Analytical Coding Scheme

Social exchanges (SEs)	Descriptors	Examples	Codes
1. Talk/spoken words	TE explains concepts, provides feedback, and asks questions to help PSTs make sense of the concepts.	Lecturer-Explanation	LE
		Questions	Q
		Feedback	FDBK
2. Writing/drawing	TE writes words or makes a drawing either on paper or chalk/white/chalkboard to help PSTs better make sense of concepts.	Words written on paper or chalk/white/chalkboard	WRTN
3. Gesture/Actions	TE uses bodily gestures/demonstrations (e.g. pointing with their finger, making an abstract drawing using their fingers, etc.) to help PSTs make sense of concepts.	Bodily gestures/demonstrations	G/A
4. Visual Representation	TE uses visual aids such as text, pictures, images, drawings, graphs, models, charts, and many others to help PSTs better make a concept.	Text	VR
		Pictorial	
		Graphical /table/charts	
		Physical objects/models	

*List of abbreviations used in the table: **TE**: Teacher educator**; PSTs:** Pre-service Teachers.

4.3.2. Challenge 2: Mapping out the different SEs on the transcripts

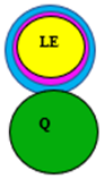
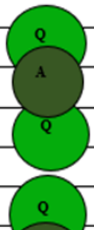
Another challenge was linked to mapping these SEs on the transcripts because I began coding by writing out these codes using text. As a result, it became difficult to trace the various manifesting MMO types from the different SE combinations emerging in the different lectures. Accordingly, the analytical methodology of using visual maps (which is also used in PCK analysis) was adopted. Mavhunga and Miheso (2021) propose that visual maps are used to outline the nature of the links among the interacting components found present in an episode. Visual maps as shown below and were used to map out the MMOs that were manifesting during various episodes of a lecture.

Keys:

Feedback (FDBK)	Visual representation (VR)	Gesture/Action (G/A)	Lecturer Explanation (LE)	Question (Q)	Answer (A)	Writing/Drawing (WTRN)	Progression of teaching across an episode	MMO type and number
FDBK	VR	G/A	LE	Q	A	WRTN		

Once the visual maps were in place, the lecture transcripts were again coded as exampled by Extract 1 below which emanated from Dr Molly's lecture during a discussion about the cell cycle with the students.

Extract 1 where Dr Molly and her students were discussing the cell cycle.

2.Defining the cell cycle	M: (**Projects slide with information about the cell cycle**) Okay let us move into the lesson, hopefully we are going to finish what we need to cover. So as said, we are going to look at what cell cycle is and then we are going to look at the different phases of the cell cycle. For the first two we are not going into the deeper details but just an overview as to what happens in the cell. The focus is going to be on Mitosis and what happens during the phases of mitosis. Right, what do you understand by cell cycle before I tell you what it is?	
	Ss: (No response)	
	M: What do you understand by the term or phrase cell cycle?	
	Ss: (No response)	
	M: You have never heard of the term or the phrase?	
	Ss: We have!	
	M: So, what is it?	
	Ss: (No response)	
	M: What is it that you don't understand, is it the cell or the cycle?	
	Ss: The cycle.	
	M: Never ever in your life?	
	Ss: Yes!	
	M: Then you do not quality to be a teacher! Okay, yes	
	S5: Cell cycle is the process whereby the cell divides to produce an identical copy of itself.	
	M: Correct that is very good, thank you any other terms?	

4.3.3. Challenge 3: Capturing the complexity of MMO types and considering students various forms of engagement

Although the revised coding scheme displayed above was successful in mapping out the manifesting MMOs and providing insights into the research questions of the study, it became clear that a MMO

resulted from any co-manifestation of any two SEs or more, where one is often a component of talk, as earlier stated. However, the initial coding scheme displayed flaws as it did not cater for the complex MMO types manifesting in the different biology lectures. As a result, I decided to categorise the manifesting MMO types into three distinct levels. Where level 1 MMO types were classified as 'basic 'as they resulted from any two SEs occurring simultaneously, with one of the SE being talk. Level 2 MMO types were classified as 'average' when they resulted from three SEs interacting with one another, where again one of the SEs is talk. Level 3 MMO types were deemed as 'complex' when they manifested from the four SEs.

Although the SEs were instrumental in the manifestation of MMOs, there were other instances where there seemed to be no student engagement or uptake of the MMOs resulting in what I characterised as a missed MMO. Such instances indicated that engagement is the necessary first step for learning as suggested by Cavanagh (2019). It became apparent that the students' form of engagement seemed to be prompted by some of the manifesting MMOs and this revelation was important in providing insights to sub-RQ2 which states, "*What forms of student engagement (if any) were elicited in the biology lectures by the manifesting meaning making opportunities*?". However, to do this effectively, I needed to be clear about what student engagement meant in this study. I could not code or ascertain the uptake or lack thereof of these manifesting MMOs without first coining student engagement and the possible causes for the observed engagements which were framed using the students' learning preferences as explained below.

Characterising student engagement

As explained in Chapter 2, this study aligns with the view offered by Fredricks et al. (2004) who conceptualised student engagement as a multidimensional activity made up of three main forms which involve: (i) affective-emotional engagement including attitudes, interest, sense of belonging, and identification; (ii) cognitive engagement including persistence, willingness, motivation, and psychological investment to learn; and (iii) behavioural engagement including participation in activities. Fredrick's et al., (2004) view was adopted because it provided multiple lenses or descriptors of understanding the various engagements that were stimulated by the use of various SEs by the biology teacher educators in their lectures. Adopting this perspective, meant that when a student was seen raising their hands, laughing, raising their hands, asking questions, answering questions, listening, critiquing, debating, taking notes, writing, drawing, demonstrating, reading, presenting, and /or listening to the lecturer or their peers, all characterised students engaging with the manifesting MMO or signalled an uptake of an MMO.

Exploring Students' learning preferences

As indicated in Chapter 2, despite the ongoing debates and critiques about the lack of validity of students' learning styles in existing research (see: Gudnason, 2017; Cuevas, 2016; Coffield et al., 2014),

the study still used them but adopted the term, 'learning preference' to attempt to bridge the gap about their lack of empirical grounding. The adoption was motivated by the fact that despite the different views expressed by the scholars (e.g. Gudnason, 2017; Cuevas, 2016) against the learning styles approach, in closer examination, they seem to all agree that different learners prefer to learn differently, thus formulating meanings differently during learning. In this study, it was observed that there were instances when certain MMO types manifested, e.g. some students would be seen to engage in a particular way e.g. a lecturer would be explaining while pointing at the visual image on the slide. This MMO would prompt various forms of engagement, where some would be looking at a teacher educator which was interpreted to mean listening, while some would be directing their attention to the screen. Others appeared to be writing, and, in some cases, some would be disengaged completely. According to Moussa (2015), four major learning styles affect how students formulate meanings and generally engage in learning. The four SEs are all outlined below:

1. Visual students learn best when teachers or lecturers use visual representations (VRs) such as maps and/or images for them to access and organise new information. For example, when a lecturer makes use of a visual image such as a 3D image of an animal cell, plays a video, or shows a diagram such MMO types are regarded as prompting visual stimulation therefore mostly engaging students who learn visually.
2. Auditory students learn best through speaking and listening as a mechanism of processing and organising the new content presented. These types of students are also referred to as aural students who learn best when teachers constantly repeat or place emphasis on the central concepts of the lecture. When lecturers use various forms of talk (such as LEs, FDBK, and Q) they were promoting MMOs that elicit listening and are more effective for students who learn auditorily.
3. These students learn best when they draw, write or read through notes to translate abstract concepts, thus teacher educators are encouraged to write (WRTN) important concepts on a board where they are accessible to such students. when a lecturer writes on the board, they foster MMOs that stimulate students to want to either read or write.
4. Kinaesthetic students process and organise information through bodily movement, hands-on or other tactile representations of information, therefore teachers are constantly encouraged to create learning opportunities that physically (G/A) or practically involve the students in the learning process. When a lecturer uses any bodily gestures or actions to demonstrate a scientific concept or allows their students to use them, they are seen as promoting MMOs that support those who learn kinaesthetically.

Learning Preferences and Topic-Specific Pedagogical Content Knowledge (TSPCK)

Learning Preferences

Learning preferences describe the varied ways in which individuals prefer to receive, process, and internalise information. Traditionally, educational research has identified categories such as visual, auditory, kinaesthetic, and read/write preferences (Fleming, 2001), which have informed differentiated instructional approaches. However, it is essential to move beyond rigid typologies that risk fixed categorisation of learners and ignoring contextual influences. Contemporary scholarship cautions against treating learning preferences as fixed or universally applicable traits, instead advocating for a dynamic and flexible understanding that situates learner preferences within their sociocultural context (Pashler, McDaniel, Rohrer, & Bjork, 2009; Willingham, 2019). This perspective is particularly pertinent in diverse educational settings such as South African universities, where students' language backgrounds, prior knowledge, and cultural norms differ yet profoundly shape their engagement with biology content.

In this study's analytical framework, learning preferences are conceptualised as fluid tendencies that interact with instructional design and lecturer agency to shape the nature of MMOs. This aligns with the theoretical grounding in Meaningful Learning Theory (Ausubel, 1968), which stresses the importance of aligning teaching strategies with learners' cognitive and cultural frameworks. Recognising and responding to these preferences is critical to fostering deeper understanding and active participation during biology lectures, especially in contexts where linguistic and cultural diversity may present barriers to engagement.

TSPCK

Although the TSPCK model (Mavhunga & Rollnick, 2013) was introduced theoretically in Chapter 2, its methodological significance requires explicit clarification in this subsection because it anchors the analytical framework for this study since it seeks to identify and explain how MMOs manifest during biology lectures. It is believed that understanding these MMOs demands attention to the topic-bound knowledge that enables lecturers to transform complex biological concepts into forms accessible to students as aspect addressed by TSPCK (Mavhunga & Rollnick, 2013).

Rather than treating Pedagogical Content Knowledge as a generic construct, TSPCK foregrounds five interrelated domains which as noted in Chapter 2 involves students' prior knowledge, curricular saliency, knowledge of what makes a topic difficult to learn, Selection of suitable representations, including analogies. According to Mavhunga and Rollnick (2013) all the five domains collectively mediate how a specific topic becomes accessible and manageable for students. In this study, these domains served as guiding concepts for both coding and interpretation of classroom episodes. For example:

- **Students' prior knowledge** was used to highlight moments where lecturers elicited or built upon learners' alternative conceptions.
- **Curricular saliency** guided analysis of how lecturers sequenced core and peripheral concepts when introducing sub-topics such as cell signalling or genetics.
- **Knowledge of what is difficult teach** drew attention to episodes where lecturers anticipated conceptual challenges or difficulties and enacted pre-emptive explanations.
- **Representations** framed the examination of visual and verbal SEs such analogues, models, drawings, gestures that functioned as vehicles for MMO.
- **Conceptual teaching strategies** illuminated the pedagogical reasoning behind specific moves (e.g., code-switching, guided questioning) that supported conceptual change.

Mapping these domains onto the data allowed observed MMOs to be linked to the underlying pedagogical reasoning of each lecturer, a connection probed further through the Video-Stimulated Recall Interviews (VSRI). Here, TSPCK operates not as a variable to be measured but as an organising heuristic for tracing how lecturers' topic-specific knowledge shapes the manifestation of meaning-making opportunities.

Integrating TSPCK into the analytical framework foregrounds lecturer agency in orchestrating the social exchanges that facilitate meaning making. It moves beyond generic pedagogical prescriptions to reveal how lecturers draw on deep content knowledge and refined pedagogical expertise to create conditions for students to construct understanding (Shulman, 1978). Through the strategic selection of language, analogies, visual aids, and formative questioning aligned to particular biology topics, lecturers bridge conceptual gaps and tailor instruction to diverse learner needs.

The framework positions learning preferences and TSPCK as mutually informing constructs that shape the quality and character of social interaction during lectures. It adopts a multilayered lens encompassing:

- the **learner dimension** (preferences, prior knowledge, linguistic and cultural context),
- the **content dimension** (topic complexity, potential misconceptions, representational modes), and
- the **pedagogical dimension** (lecturer TSPCK, instructional strategies, discourse practices).

This integrative stance aligns with Sociocultural Theory (Vygotsky, 1978), which views meaning making as co-constructed through mediated interaction, with the lecturer's specialised knowledge functioning as a primary tool for scaffolding student learning within their contextual realities.

By situating learning preferences within a dynamic sociocultural frame and highlighting the central role of TSPCK in enabling lecturer agency, this analytical framework advances a nuanced understanding of how MMOs manifest in biology lectures. It addresses the complexity of teaching and learning in diverse higher-education settings while offering actionable insights for enhancing lecturer practice to support inclusive and conceptually rich biology education.

Once these conceptual clarifications and operational definitions were established, the coding process resulted in the final coding scheme used to document emergent MMO types and forms of student engagement, as summarised in Table 4.2.

Table 4.2 Final analytical coding scheme

Social exchanges (SEs)	Descriptors	Examples	Codes	Possible form of student engagement that may be elicited
Talk/spoken words	TE explains concepts, provides feedback, and asks questions to help PSTs make sense of the concepts.	Lecturer-Explanation	LE	Students looking at the TE and/or screen, some writing notes
		Questions	Q	Some students raising their hands, some answer questions, and some writing notes
		Feedback	FDBK	Students looking at the TE and/or screen, some writing notes
Writing/drawing	TE writes a word or makes a drawing either on paper or chalk/white/chalkboard to help PSTs better make sense of concepts.	Words written or drawings on paper or chalk/white/chalkboard	WRTN	Students looking at the TE and/or screen or chalkboard, some taking notes or making drawings made by the TE.
Gesture/Actions	TE uses bodily gestures/demonstrations (e.g. pointing with their finger, making an abstract drawing using their fingers, etc.) to help PSTs make sense of concepts.	Bodily gestures/demonstrations	G/A	Students looking at the TE, some writing notes
Visual Representation	TE uses visual aids such as text, pictures, images, drawings,	Text	VR	Students looking at the lecturer and/or screen, some writing notes
		Pictorial		
		Graphical /table/charts		

	graphs, models, charts, and many others to help PSTs better make a concept.	Physical objects/models		

*List of abbreviations used in the table: **TE**: Teacher educator**; PSTs:** Pre-service Teachers.

Using the above coding scheme enabled me to focus on the manifesting SEs and their impact on the students' engagement, thus Fraser (2013) asserts that teaching informs learning and vice-versa. Below I provide insights using examples of how data was analysed first per episode (explained in greater detail in Chapter 3) and per lecture using the final analytical coding scheme presented above.

4.3.4. Example of how the SEs were used as codes to represent the manifesting MMOs in a lecture episode

Once the SEs were coded and visual maps were drawn up to capture the manifesting MMOs, it became apparent that there were times in the lectures when the SEs were occurring simultaneously as shown in Figure 4.1 below.

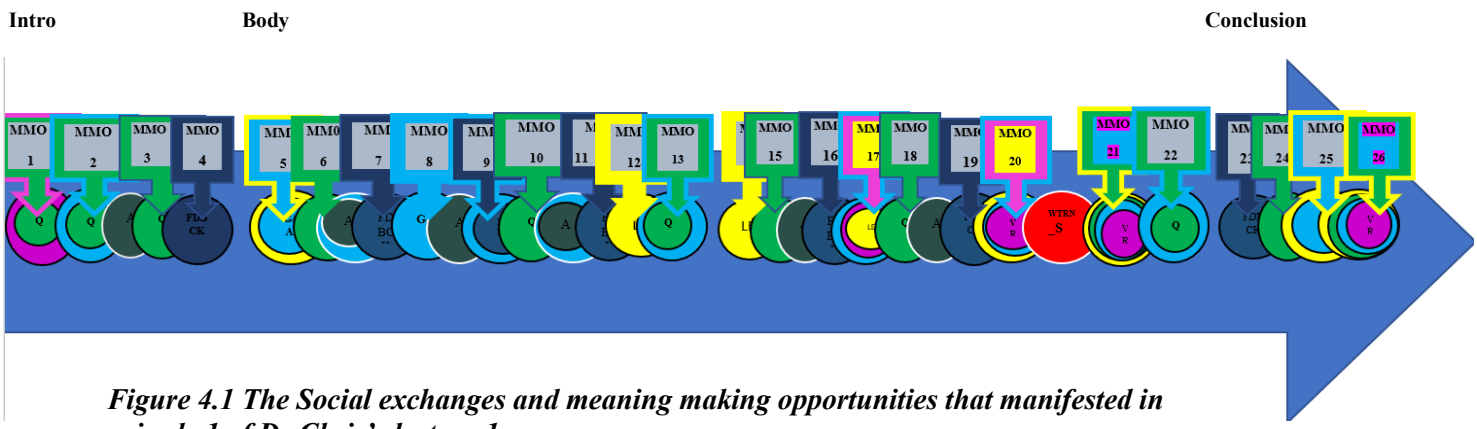


Figure 4.1 The Social exchanges and meaning making opportunities that manifested in episode 1 of Dr Chris's lecture 1.

Interpretation of Figure 4.1 (refer to Extract A captured in Chapter 3)

Figure 4.1 shows that the first MMO that manifested at the beginning of Dr Chris's lecture episode was a visual representation, which is represented by a **purple visual map**. From the video recording, this visual representation was a slide showing a 3D image of an animal cell. Within the purple visual map is a green one representing a question **type of SE.** The green visual map is wholly inside the **purple** one because as Dr Chris was projecting the 3D animal cell image, he also posed this question simultaneously: "…*why is it a 3D picture?"*. The **green visual map** is placed inside the **purple visual map** to show that the two social exchanges were used simultaneously by Dr Chris which led to the manifestation of MMO **1**. During this MMO, the students could be seen in the video looking up at the screen, which signalled that they were engaged during this MMO. One of the students answered the

question posed by Dr Chris and said "*I think that it shows the dimensions*" represented by the **dark green visual map.** This provided evidence that the students had engaged with the content being presented and were able to formulate meaning from the projected visual. Therefore, the manifestation of these two SEs which occurred simultaneously (VR+Q) was considered as **MMO 1** (represented by the **green arrow**) during this introductory segment.

Dr Chris then pointed at the screen again which is a form of gesture or action-type of SE (represented by the **blue visual map),** and he then asked the students a question '*Which dimensions?'* (Represented by the second **green visual map** inside the **blue visual map)** and this question was based on student 1's response. Again, **MMO2** resulted because of the manifestation of two social exchanges (G/A+Q) that were used by Dr Chris during this introductory phase of this episode. Student 2 responded by saying *"The 3 dimensions, like the front part, the side part, and the top parts"* (represented by a **dark green visual map**), this again provides evidence that the student was able to successfully make meaning out of this opportunity that manifested in Dr Chris's lecture.

MMO3 resulted from Dr Chris asking a follow-up question based on student 2's response represented by the **green visual map**. Dr Chris asked students "*Which are the L lines?".* Unfortunately, during this MMO, the students did not seem to know the answer, as none of them raised their hands. Although Dr Chris had successfully generated an MMO through questioning (Q), this was considered an unsuccessful or missed MMO given that the students were unable to make meaning during this opportunity. To conclude the introductory phase of this episode, **MMO4** manifested which resulted in Dr Chris providing student 2 with feedback as represented by the **navy-blue visual map-a type of talk, SE.** Dr Chris provided feedback by saying "…*you were supposed to say that it shows the 3 dimensions*". This then supports the argument proposed by Scott and Mortimer (2012) that questions are important tools that can be used during meaningful learning to identify and diagnose students' gaps in their understanding. From the above analysis, it can be deduced that a total of four MMOs manifested in the introductory phase of this episode through the use of six social exchanges being **visual representation interacting with a question** (VR+Q)/ **gesture/action interacting with a question** (G/A+Q)/ **question** (Q) and **feedback** (FDBK.

Figure 4.1 above, shows that there was a shift from the introductory segment to the body of this episode, hence the space between the visual maps. This shift was denoted by Dr Chris's use of the phrase "O*kay, let's move on!".* The body segment of episode 1, as seen in Figure 4.1 shows that Dr Chris began by providing an explanation (represented by the **yellow visual map-a type of talk, SE**). While Dr Chris explained about the 3 dimensions which are length, breadth, and height he was using his body to demonstrate these various parts (represented by the **blue visual map** indicating a gesture and/or action-a **type of SE** inside the **yellow visual map, (**showing that the two SEs were happening simultaneously) It can be said that the occurrence of these two SEs simultaneously resulted in the generation of **MM05**

in this segment. To ascertain if his students understood his explanation and demonstrations of the different parts that make up 3 dimensions, Dr Chris asked his students the following question "…*is this length?"* (represented by the **green visual map**). The use of this question resulted in the manifestation of **MMO6.** During this MMO the students replied in unison and said '*No, height*' (represented by **a dark green visual map**), They were also using their bodies to demonstrate the correct height dimension. **MM06** manifested when Dr Chris was providing feedback that validated the correctness of the student's response, as he re-voiced their response. In this first part of the body segment, there was a total of 7 MMOs that manifested in Dr Chris's lecture (depicted as **MMO5-MM013** in Figure 4.1). **MMO 13** manifested when Dr Chris consolidated the episode, by re-explaining the three parts that make up dimensions using demonstrations. Hence the **yellow visual map** indicating lecture explanation **(LE)** is shown inside the **blue visual map**-indicating actions and/or gestures showing that the two SEs were occurring instantaneously. A total of 7 opportunities in this segment were generated through **lecture explanation interacting with gestures and or actions (LE+G/A)/Question (Q)/ feedback (FDBK)/ gestures and or actions (G/A)/ gestures and or actions** interacting with **feedback ((G/A+ FDBK)/ Question (Q)/ feedback (FDBK)/ lecture explanation (LE) and lecture explanation interacting with gestures and or actions (LE+G/A)**. These results revealed that Dr Chris created a repertoire of MMOs to help his students understand the concept of 3D better, taking into consideration that when asked a question they were able to provide a correct response.

There was again another shift in the first part body segment moving to the second part of the body segment and it was signified by the phrase *"Now I would like you to make 2D diagrams."* This phrase showed that Dr Chris had completed the segment about the three parts that made up 3 dimensions and he now wanted his students to engage in the next activity. As revealed by Figure 4.1 in the second part of the body segment, Dr Chris generated 9 more MMOs shown as **MM014-MMO21**. Out of the 9 opportunities, **MM017 and MMO20** became interesting because this was the first time that Dr Chris had generated an MMO that resulted from 3 SEs that were used concurrently. Both cases involved **gestures and/or action** represented by the blue visual map interacting with a visual representation shown by a purple visual map while also interacting with lecturers' explanation represented by the yellow visual map. This appeared to be more complex than the other SEs that resulted from 2 SEs. For example, during **MMO20** Dr Chris pointed at the projected 3D animal cell and explained to his students that they had 5 minutes to draw a 2D labelled diagram of an animal cell, hence the visual map showed the yellow **(LE)** and purple visual map **(VR)** inside the blue **(G/A)- (**showing that they were all occurring simultaneously). In the video, the students were seen making drawings of the 2D animal cells which provided evidence that they were actively engaged during the MMO.

MMO 21 was another interesting opportunity that resulted from 4 SEs interacting with one another, and it appeared to be even more complex than the SEs that manifested from the 3 SEs. This MMO manifested when Dr Chris again explained to the students what they were expected to do during this

segment of the lecture. He walked around observing their various drawings and referred them to the projected 3D animal cell on the screen to ensure that they were clear on what they needed to include in their 2D drawings and asked them whether they understood (represented by the yellow visual map) and asked questions (represented by the green visual map inside the yellow visual map) while pointing at the projected visual representations (represented by the blue and purple visual map inside the yellow and green visual maps). This shows that the 4 SEs were occurring concurrently as a means of further guiding the students who were already engaged in making their drawings. In the second part of the body segment, 9 MMO resulted from the use of the following SEs. These are **lecture explanation (LE)/ Question (Q)/ gestures and or actions** interacting with **visual representations** interacting with **lecture explanation (G/A+VR+LE)/Question (Q)/ feedback (FDBK)/ gestures and or actions** interacting with **visual representations** interacting with **lecture explanation(G/A+VR+LE), lecture explanation** interacting with a **Question** interacting with **gestures and or actions** interacting with **visual representations (LE+Q+ G/A+VR) and gestures and or actions** interacting with a **Question (G/A +Q).** Again, this MMO involved students in making 2D drawings of animal cells.

Again, there was a shift from the second part of the body segment moving towards the concluding phases of the episode. This shift was evidenced by the phrase "*Okay, now I want us to look at these organelles in a closer view*." This means that, during this phase, Dr Chris was consolidating students' understanding of the organelles that they drew in their 2D diagrams. Figure 4.1 above also highlights that in the concluding phase of the episode, there was a total of 4 MMOs that manifested in this episode. Dr Chris began the episode by providing students with general feedback (represented by the **navy-blue visual map**) of the students' drawings that he saw as he was walking around the venue. Dr Chris then asked his students a question (represented by the **green visual map)** about whether they saw the relationships amongst the organelles that they were drawing. This question was rhetorical in nature as the students were not expected to answer. Dr Chris explained the relationship while pointing at the 3D image of the animal cell (represented by the blue visual map inside the **yellow visual map,** showing that they are happening at the same time). He used a combination of 4 SEs which involved **lecture explanation** interacting with a **Question** interacting with **gestures and or actions** interacting with **visual representations (LE+Q+ G/A+VR)**.

Summary of results of Episode 1 of Lecture 1 of Dr Chris

Figure 4.1 above indicates that numerous MMO types manifested in this episode, some of which were more complex than others. All these manifesting MMO types engaged students in various ways including listening to explanations, answering questions, and making 2D drawings which all signified that students were engaged in these manifesting MMOs in Dr Chris' lecture.

4.3.5. Categorisation and analysis of codes per lecture

After the SEs and forms of student engagements were coded per episode across the various lectures, they were categorised in their respective levels as depicted by Table 4.3 below using an example from Dr Ellens's lecture.

Table 4.3. Summarised findings of the MMO types that manifested in Dr Ellen's lectures and the forms of engagements prompted

Levels of MMOs	Description of each level	Types of MMOs manifesting across the two lectures	Manifesting forms of engagement across the two lectures
1	**Combination of two types of SEs**	1 Q.+ FDBK 2.LE+Q 3. LE+G/A 4. LE+VR 5. FDCK+ANLG	**-Most students are looking at the screen** **-Some students are looking at the demonstrations and engaged** -Most students have **their hands raised** and some are asking questions whilst others are asking questions **-Most students are making notes** **-Most students are listening to the lecturer and engaged** **-Most students are discussing the questions posed with their peers and some not discussing** **- Some students are seen laughing**
2	**Combination of three types of SEs**	1.ANLG+G/A+Q 2.GA+VR+LE 3. Q+ FDCK+G/A 3 Q+FDCK+LE 4. FDBK+G/A+WRTN 5. LE+G/A+WRTN 6. FDBK+ G/A+VR	**-Most students are looking at the screen** **-Some students are looking at the demonstrations and engaged** -Most students have **their hands raised** and some are asking questions whilst others are asking questions **-Most students are making notes** **-Most students are listening to the lecturer and engaged** **- Most students are discussing the questions posed with their peers and some not discussing** **- Some students are seen laughing** **--Some students are seen engaging with the lecturer**
3	**Combination of four types of SEs**	1.LE+G/A+VR+Q 2. Q+ FDBK+G/A+VR 3. LE+G/A+VR+ANLG 4. FDCK+LE+G/A+VR **5.** LE+WRTN+G/A+Q	**-Most students are looking at the screen** **-Some students are looking at the demonstrations and engaged** -Most students have **their hands raised** and some are asking questions whilst others are asking questions **-Most students are making notes** **-Most students are listening to the lecturer and engaged** **-Some students are discussing the questions posed with their peers** **- Some students are seen laughing** **--Some students are seen engaging with the lecturer**

*List of abbreviations used in the table: **SE**: Social Exchanges, **MMOs:** Meaning making Opportunities; Q: Question(s); **LE**: Lecturer Explanation(s); **FDBK**: Feedback; **VR**: Visual representations; **WRTN**: Writing; **G/A:** Gestures and/or actions

Table 4.3 above, reveals that a total of 16 MMO types manifested in Dr Ellen's lectures. Out of the 16, there were a total of 5 MMO types that appeared in level 1 which manifested from two SEs used simultaneously by the lecturer. 6 MMOs that were classified at level 3 resulting from all four different SEs. These results indicated that most of the MMOs types that manifested in Dr Ellen's lectures ranged at level 2 and they mainly catered for students with two or three learning preferences, given that they manifested from the combination of three SEs interacting with one another. This meant that the MMO types that manifested in Dr Ellen's lectures often accommodated students with three learning preferences.

What was also deduced from Table 4.3 above is that these various MMOs prompted various forms of student engagement which involved students raising their hands, answering questions, listening to the lecturer's explanations (evidenced by students looking at the lecturer), students writing notes, and many others. These forms of engagement, in most cases, revealed that the MMO types at different levels that manifested in Dr Ellen's lectures were taken up by most students. Although the word "some' reflected in the student engagement category revealed that some of the students were not engaged by these MMO types of various complexities. The reason for this finding was associated with the fact that different students have different learning preferences (see Chapter 2), which ultimately influence how to formulate meaning during learning.

4.4. Conclusion

This chapter gives an overview of the development of the analytical framework which is supported by the four SEs, which involves talk, writing and/or drawings, visual presentations, gestures, and/or actions. These SEs are considered cultural and mediational tools that are used to map out the manifesting MMOs in various biology lectures. It became apparent during the analysis that when internalised by the students, they appeared to elicit various forms of student engagement, which seem to correspond with the students' various learning preferences. Thus, these four constructs (SEs, learning preferences, students' forms of engagement and TSPCK components) were fundamental frames that were used to analyse the data of this study and were deemed suitable because as earlier explained, they were all aligned with the theoretical frameworks of this study as explained in Chapter 2. The next chapter presents the first case analysis of Dr Chris's lectures.

Chapter 5

Case 1: Dr Chris

Topic taught: Cell biology

Class: 1st year natural sciences pre-service teachers

5.0. Introduction

Chapter 4 introduced the analytical framework that underpins this study. To map out the manifesting MMOs, SEs, learning preference and engagement became central concepts for the development of the analytical framework. An MMO in this study was characterised by the co-manifestation of any two SEs simultaneously, in which one of those SEs is talk. I chose to focus on other forms of talk which included lecturer explanation (LE), feedback (FDCK), questions (Q) and mnemonics (MNMC). Student engagement was aligned with the view offered by Fredricks et al. (2004) who conceptualise it as a multidimensional activity made up of three main forms which involve: (i) affective-emotional (ii) cognitive engagement and (iii) behavioural engagement as explained in Chapter 2. This meant that when students were seen raising their hands, laughing, asking or answering questions, critiquing or debating, taking notes, writing, drawing, demonstrating, reading, presenting, listening to the lecturer or their peers and more, all characterised an uptake of the manifesting MMO during a lecture.

The section below presents the background information of Dr Chris as a means of framing the findings. To conclude the chapter, I provide insights crucial for answering the research questions that guided this study.

5.1. Dr Chris' Background information and lecture overview

Table 5.1 below presents a summary of Dr Chris' background information and an overview of the two lectures under observation, as a means of contextualising the results of this study. The information presented in Table 5.1 is further expanded upon in the subsequent sub-sections below (also see Chapter 3).

Table 5.1. Dr Chris' summarised background and lecture information

Name of Lecturer	Age/Race/Experience	Qualification/s held	Teaching Philosophy	Class taught	Duration of the lectures/minutes		Number of PSTs taught	Content taught
					Lecture 1	Lecture 2		
Dr Chris	African male. About 55 years old. Teaching experience of more than 30 years.	B.Ed., BSc. Ed. MEd, PhD.	Inclusion, and Constructivism (particularly cognitive and social constructivism)	1st year NS PSTs	48	86	120	Introduction to cell biology

5.1.1 Content overview of cell biology and the challenges associated with teaching the topic

Fernández and Tejada (2018) argue that cell biology is a topic that deals with the study of cells and their functions, ranging from their sub-cellular activities which keep them functioning, to the way that cells communicate with each other. According to Campbell et al. (2018) and Simon (2021), the study of cell biology covers the scope of both prokaryotic and eukaryotic cells. Prokaryotic cells are characterised by their simpler structure, lack of membrane-bound organelles and their genetic material which is housed in a nucleoid. In contrast, eukaryotic cells are more complex, found in plants, animals, and fungi and protists. This complexity is attributed to the presence of membrane-bound organelles, including the nucleus, mitochondria, and endoplasmic reticulum, which contribute to their specialised functions (Campbell et al., 2018; Simon, 2021). The plasma membrane, as described by Campbell et al. (2018), is a selectively permeable barrier that encloses cells, regulating material exchange and facilitating communication with the external environment. Structurally, it consists of a phospholipid bilayer embedded with proteins, glycoproteins, and glycolipids. These components enable critical processes such as osmosis, diffusion, and active transport, which collectively maintain cellular homeostasis (Campbell et al., 2018; Shen, 2020).

Within the cytoplasm, Campbell et al. (2018) say that eukaryotic cells house various organelles, each fulfilling specific roles as explained below:

- **Nucleus**: Acts as the control center, containing genetic material and overseeing cellular activities, such as protein synthesis and cellular division.
- **Mitochondria**: Referred to as the cell's powerhouse, mitochondria release energy from biochemical compounds through cellular respiration.
- **Chloroplasts** (in plant cells and algae): Facilitate photosynthesis by converting solar energy into chemical energy stored as starch.
- **Endoplasmic Reticulum (ER) and Golgi Apparatus**: Both are integral to synthesising, modifying, and transporting proteins and lipids throughout the cell.
- **Lysosomes and Vacuoles**: These organelles are involved in waste management and storage, ensuring the cell’s internal environment remains conducive to its functions.

Cell biology is one of the unifying topics in biology, meaning that it is key to understanding other biological processes and phenomena, including the general functioning of living organisms (Fernández &Tejada, 2018). The knowledge of cell biology affects students’ everyday lives, and it has the potential of helping them make important informed decisions regarding issues related to reproduction, nutrition, and their overall health (Fernández & Tejada, 2018). Hence, Carlen et al. (2014) further argue that the

concepts covered in the topic of cell biology are crucial for scientific literacy, as they permit students to have a wider understanding of the world, as well the ecological relationships between living organisms and their functions in the ecosystems. However, there are numerous challenges that are faced by both teachers and learners when engaging with the topic. The structures involved (i.e. the cell itself and its organelles) are microscopic. As such, the descriptions of structure and functions become very abstract as they happen at cellular and sub-cellular levels of organisation. What further worsens the problems associated with learning the topic is that most teachers often fail to use appropriate teaching methodologies which negatively affects their students learning (Fernández & Tejada, 2018). Many teachers fail to apply a multimodal and interactive teaching approaches aimed at helping learners visualise the relationships between cell structures and their functions resulting to the development of conceptual understanding. Another challenge that is highlighted by Veselinovska et al. (2011) that is also associated with teachers' poor methodological practices when teaching the topic concerns the scale and size of the visual aids that they use, which often does little to nothing in stimulating and mediating students' understanding of the structure and functions of cells. Thus, Fernández and Tejada (2018) argue that the topic of cell biology is not a straightforward topic to teach like many other biology topics. Even so, teachers are still encouraged to use a repertoire of student-centered teaching strategies that will help move students learning from over-dependent learning to independent learning, passive to active, surface to deep learning. Also, biology teachers are encouraged to use a variety of teaching strategies that promote the overall development of 'generic skills' of a scientist including communication skills, cooperative skills, and problem-solving skills (Veselinovska et al., 2011). According to Veselinovska et al. (2011) such teaching strategies involve case studies, group work, discussions in large classes, posters, use of concepts maps, stimulating visual aids, demonstrations and many other.

5.1.2. Context of the lecture, resources and technologies used by Dr Chris

Dr Chris's lectures took place in an exam hall, which was one of the biggest venues at SAX that could accommodate all the 200 first-year natural sciences students enrolled for the module. The exam hall's layout allowed the students to be seated individually in vertical and horizontal rows with spaces that permitted Dr Chris to move in between each row as depicted in Figure 5.1 below.

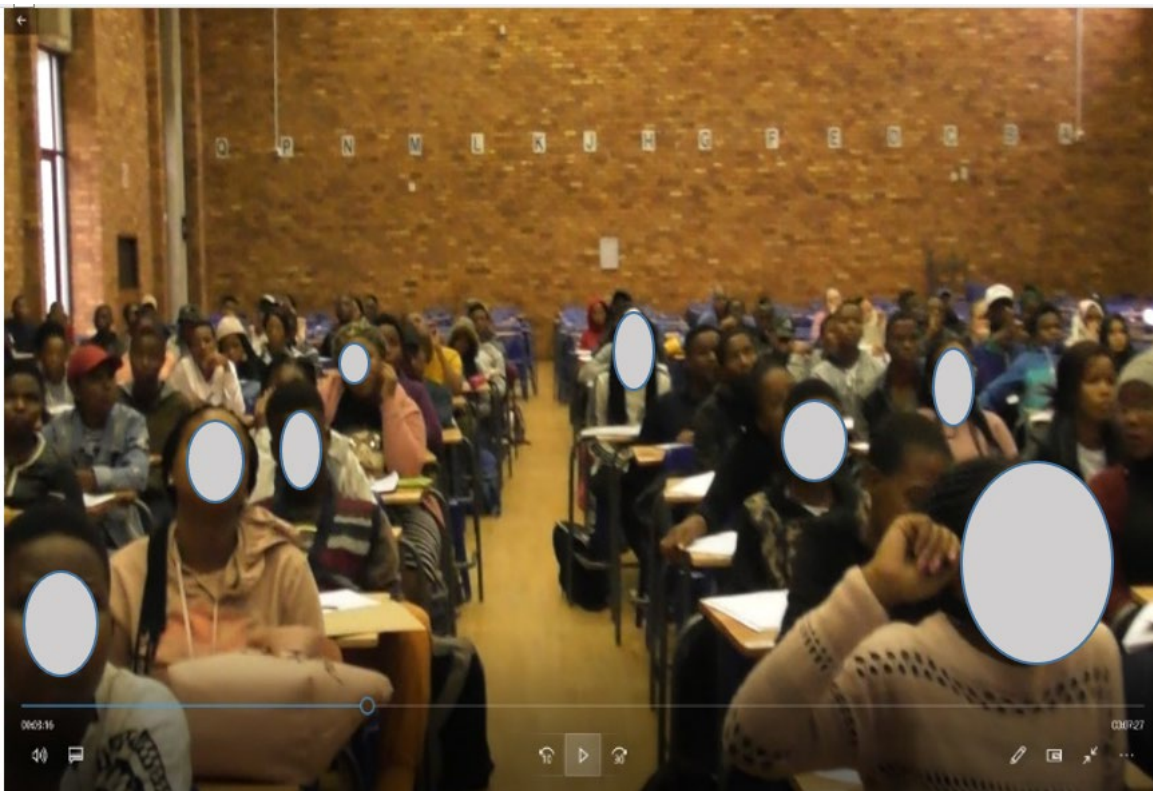


Figure 5.1 Layout of Dr Chris's lecture venue

During lecture 1, Dr Chris used prepared presentation slides (which contained colour 2D and 3D images of plant and animal cells and plain black and tabulated text) as one of the main T&L resources. In lecture 2, students presented in small groups about the previously covered organelles of the animal cell. During this lecture, only four groups presented due to time constraints and other groups were then scheduled to present in the following lecture. The four group presentations covered the structure and functions of the following organelles: Smooth and rough Endoplasmic Reticulum (ER), Microtubules, Cytosol and Plasma Membrane. After each presentation, Dr Chris facilitated a whole class discussion that was aimed at consolidating and placing emphasis on the key concepts that were covered by the various groups. The technology that was available and used in both lectures was a data projector and one screen that was put up in the front of the exam hall. The 200 students had to look at the screen during the lectures, as there were no handouts of the prepared slides.

5.2. Presentation of the findings

Dr Chris was observed delivering two consecutive lectures in varying durations. Lecture 1 a single period of 45 minutes, comprised of a total of four episodes, while lecture 2 a double lecture of 90 minutes had a total of five episodes. Across both lectures, twelve distinct MMO types were identified, with a total frequency of 129 occurrences manifested, as summarised in Table 5.1 below.

Table 5.2 Summarised findings of the types of social exchanges and MMOs that manifested in Dr Chris's lectures

Levels of types of MMOs	Description of each level	Types of MMOs manifesting across the two lectures	Frequency of type of MMO across lectures	Manifesting forms of engagement across the two lectures
1	**Combination of two types of SEs**	1. [VR+Q]	**20**	**-Most students are looking at the screen** -Some students have **their hands raised and are a**nswering questions **-Some students are making notes -Some students are listening to the lecturer while a few** are **disengaged-looking elsewhere - Most students are seen laughing** - **Some** students are **presenting**
		2. [G/A+Q]	**14**	
		3. [LE+G/A]	**9**	
		4. [FDBK +Q]	**11**	
		5. LE+Q]	**12**	
		6. [ANL+G/A]	**2**	
		Proportion of the total frequency of MMOs	**68**	
		Proportion of the total (in %)	**53**	
2	**Combination of three types of SEs**	1. [GA+VR+LE]	**23**	**-All students** seen **drawing -Most students** are seen **looking at the screen -Most students** have **their hands** raised and answering questions **-Some students** are **seen writing or making notes -Most students** are **seen listening while** some students are **disengaged-looking elsewhere -Most students are seen laughing -Some** students are **presenting**
		2. [Q+G/A+VR]	**13**	
		3. [FDBK+ G/A+VR]	**13**	
		Proportion of the total frequency of MMOs	**49**	
		Proportion of the total (in %)	**38**	
3	**Combination of four types of SEs**	1. [LE+Q+G/A+VR]	**5**	**-All students** seen **drawing -Most students** are seen **looking at the screen -Some** students are **presenting -Most students** have **their hands** raised **-Some students** are **seen writing or making notes -Most students are seen laughing -Most students** are **seen listening** -Some students are **disengaged-looking elsewhere**
		2. FDBK] +Q+G/A+VR]	**5**	
		3. [LE+Q+G/A+VR]	**2**	
		Proportion of the total frequency of MMOs	**12**	
		Proportion of the total (in %)	**9**	

Table 5.1 reveals that the twelve different MMO types were classified into three distinct levels, ranging from simple to complex combinations as shown in Table 5.1 above. The first row of Table 5.1 shows that out of the twelve types of MMOs that manifested in Dr Chris's lectures were classified into three respective levels. At level 1, there was a total of six types of MMOs that resulted from two SEs used simultaneously and these were simple in nature and had the potential of accommodating students with one or two learning preferences, depending on the SE combination. The level 1 MMO types had a total frequency of 68 out of 129 in the two lectures. The second row revealed that, out of the twelve, there was a total of three MMO types that resulted from the concurrent use of three different SEs by Dr Chris, and these were categorised at level 2. The MMOs types manifesting at level 2 were deemed as moderate in nature and had the potential of accommodating students with two or three learning preferences, contingent on the resulting SE combination. The level 2 MMO types had a total frequency of 49 out of 129. The third row revealed that out of the twelve there was a total of three MMO types that resulted from the combination of four SEs used simultaneously and these were classified at level 3 and were more complex in nature, thus having the potential of catering for students with three or four learning preferences. The level 3 MMO types had a total frequency of 12 out of 129.

In the sections below, I explain in greater detail how these combinations manifested in Dr Chris's lectures ranging from simple to complex and the extent to which these opportunities were effective in engaging the students during the lectures.

5.2.1. Level 1 type of meaning making opportunities

Table 5.1 above revealed that the types of MMOs that were classified as level 1 were characterised by the combination of two SEs used simultaneously, making them simple in nature in comparison with the other two categories. The level 1 MMO types had a total frequency of 68 out of 129 across the lectures. The data table further revealed that six types of MMOs that manifested in Dr Chris's lectures included:

1. A visual representation and a question [VR+Q]
2. A gesture and/or action and question [G/A+Q]
3. Lecture explanations and gesture and/or action [LE+G/A]
4. Feedback and question [FDBK +Q]
5. A lecture explanation and question [LE+Q]
6. An analogy and gesture and/or action [ANL+G/A]

In the sub-sections below, I further explain and provide instances of how these SE combinations resulted in the manifestation of various MMOs in Dr Chris's lectures.

Meaning making Opportunities resulting from a combination of visual representations and questions [VR+QI

The findings from the analysis of Dr Chris' lectures showed that a visual representation alongside a question was one of the combinations at level 1 that resulted in the manifestation of MMOs. This type of MMO had the highest frequency of 20 out of a total of 68 in this category or level. Such MMOs resulted when Dr Chris used a visual representation to pose a question in episode 3 of lecture 1. During this episode, Dr Chris conducted a whole class discussion about the structure and function of the nucleus of a cell. The students were asked by Dr Chris to look at the projected image which showed a 3D diagram of the animal cell (indicating a VR) as shown in Figure 5.2 below while asking them a question, "*And if you look at those organelles that are in the cell which one of them is the largest?".* According to Jevons (2022), this type of question is a close-ended question because there is only one correct answer that the teacher is anticipating.

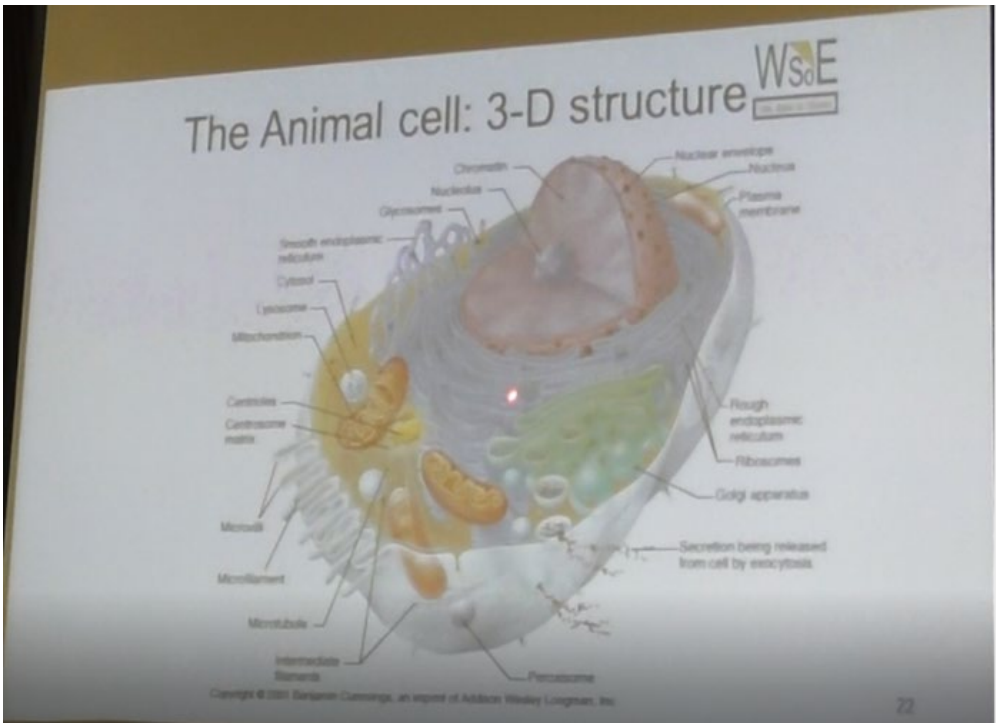


Figure 5.2 Image of a 3D animal cell

At this point, when watching the recorded video most of the students were seen looking at the screen which signalled they were engaging with the visual thus the manifesting MMO. While some of the students had already raised their hands as illustrated by Figure 5.3 below, again revealing students' further engagement with the manifesting MMO.

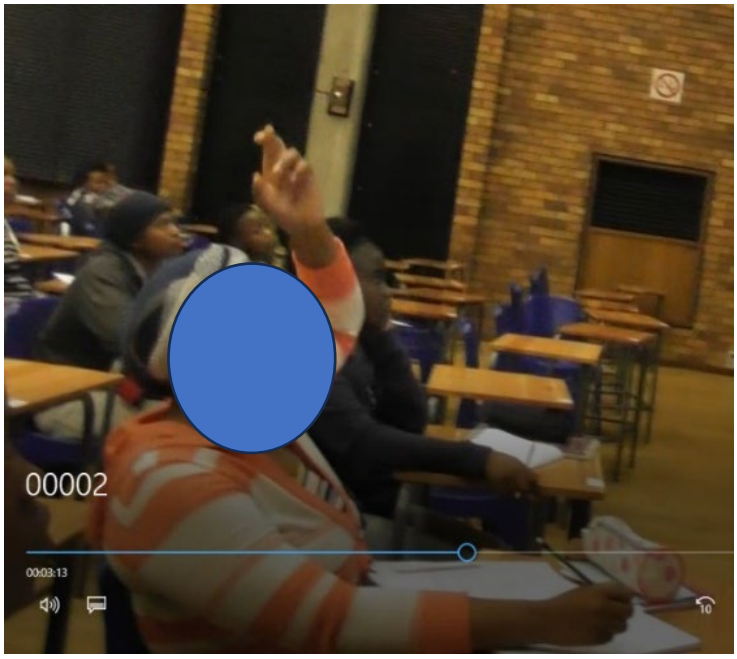


Figure 5.3 Students engaging with the projected visual

One of the students responded that the largest organelle was the "*nucleus*". This supports the argument presented by Eliasson, et al., (2017) that the use of both questions and visuals is important in helping lecturers to engage and guide students in formulating accurate scientific meanings during lectures. These results show that there is a need for biology lecturers to incorporate visual stimulants during their lectures, to support students' understanding of abstract biology concepts.

Meaning making Opportunities resulting from a combination of gestures and/or actions and questions /*Q+G/A]*

The combination of questions alongside gestures and/or actions was another type of combination that manifested in Dr Chris's lectures. This MMO type had the second-highest frequency of 14 out of a total of 68 at this level. MMOs were characterised by instances where Dr Chris would ask a question while gesturing or performing an action. Such an instance manifested in episode 2 of lecture 2 where Dr Chris facilitated a whole class discussion to ensure that the other students were listening to group 1's presentation based on the endoplasmic reticulum (ER), which was one of the concepts covered in lecture 1. During this episode, Dr Chris asked students a question "*Anyone who was listening? There are two types of cells that they mentioned and what were they?"* This was again another closed-ended question which required the students to recall the two types of cells that group 1 had mentioned. While Dr Chris was asking this question, he simultaneously showed his two fingers (to represent the number two-indication an action or gesture) emphasising the number of cells he was asking about. During the manifestation of this MMO, some students were looking at Dr Chris (which was interpreted to mean that they were listening-signalling engagement) while a few had

raised their hands, which evidenced that the students were further engaged. Student 3 then tried to answer the question but was inaudible as they were seated at the back and did not have a microphone, Dr Chris then asked student 3 to use their 'teacher voice' so they could be audible. Student 4 interjected and responded, "*Muscle cells and liver cells*". This incident further provides evidence that group presentations followed by lecturer or teacher questions play an integral role in promoting collaborative learning (Li et al., 2022) during MMOs.

Meaning making opportunities resulting from a combination of analogy and gestures and/or actions *[LE+G/A]*

The data shows that lecturer explanations alongside gestures and/or actions were another combination that led to the manifestation of MMOs in Dr Chris' lectures. This type of MMO had a frequency of 9 out of a total of 68 at this level. This combination resulted in episode 11 of lecture 1 where Dr Chris and his students had a whole class discussion about the difference between the structure of plant and animal cells. He then summarised the structural difference by explaining that "*All these other organelles besides the different ones that we have mentioned are basically the same, except plant cells do not have centrioles like that in animal cells. I think that is one that we forgot to mention*" During the explanation, Dr Chris simultaneously used his fingers to demonstrate the structure of centrioles. This suggests that he was again emphasising the structure of the centrioles which might show that he was aware that an explanation on its own was not enough to explain the abstract structure. That is why Thörne and Gericke (2013) encourages biology teachers to use visual stimulants or gestures during explanations to help learners visually connect with abstract concepts. This was no exception in Dr Chris' lecture because during the explanation some students were looking at Dr Chris which indicated that were listening thus providing support that this type of MMO engaged them.

Meaning making opportunities resulting from a combination of lecturer explanations and questions [LE+Q]

Lecturer explanations and questions were another type of SE combination that manifested in Dr Chris' lectures, with a frequency of 12 out of a total of 68 in this category. Such a combination was exemplified by episode 2 of lecture 2 where Dr Chris was consolidating group 1's presentation about the ER, another organelle that was covered in the previous lecture. During this instance, Dr Chris explained to his students that "*They spoke about the typical animal cell and its structures and which did we say has an abundance of ER?"* Without giving students, a chance to respond he further explained saying *"I am telling you the answer, is the liver and muscle cells have an abundance of ER as they had mentioned."*. According to Smith et al., (2011) such a question is considered a hypothetical or rhetorical question and is usually aimed at mentally stimulating students' thinking rather than seeking a response. In the video, although many students were looking at Dr Chris some were murmuring which signalled that they were thinking about the posed question, and they were engaged during this MMO. Thus, Grinath et al., (2019)

argue that teachers often use questions that are hypothetical in nature alongside explanations to not just assess their students' understanding of the explained concepts but to enable them to think about their thinking or knowledge.

Meaning making opportunities resulting from a combination of feedback and questions [Q+ FDBK]

The data depicted in Table 5.2 above reveal that question and feedback were another type of SE combination that led to the manifestation of MMOs in Dr Chris's lectures. This MMO type used had a frequency of 11 out of a total of 68 at this level. Both questions and feedback were characterised as components of talk. Episode 10 of lecture 1 exemplified an instance where such an MMO manifested. Dr Chris and his students engaged in a whole class discussion about the flagellum. He began this episode by asking students to look at the back of the projected 3D image of an animal cell and asked them what is it that they see, as shown in line 1 of **extract A** below. This was again another closed-ended question that required students to give a one-word answer.

Extract A

1. *C: …This is from that image, there is something else at the back, what is that?*
2. *Ss: (murmuring)*
3. *C: It is?*
4. *Ss: Flagellum*
5. *C: Flagellum, which cell has the Flagellum?*
6. *Ss: (murmur)*
7. *C: Sorry? (Walking around) Which cell has a Flagellum? (Repeats the question) Yes! (Pointing at the student who has their hand up)*
8. *S10: A bacteria cell*
9. *C: Yes, a bacteria cell does have a flagellum, but this is a eukaryotic cell we are talking about. Although he is right, some bacteria cells do have a flagellum, but we are talking about a eukaryotic cell that has a tail. Uhmmm*

Line 2 of Extract A above shows that the students were murmuring (a signal of engagement and uncertainty), and no one had raised their hand to provide a direct response. In line 3, Dr Chris then asked another prompting but close-ended question *"It is?"*. This question signalled to the students that he wanted a direct answer from them. The students then replied in unison to say that the structure in question was a flagellum evidencing their engagement during this MMO. Dr Chris then re-voiced the students' answer as shown in line 5 and simultaneously asked again which cell has the flagellum. Line 6 reveals that students again murmured their responses which was again interpreted to mean that they were still not sure about the responses that they were thinking about (signalling engagement). In line 7 Dr Chris repeated his question to again signal to his students that he still waiting for a direct response. Student 10 then responded by saying that it is a bacteria cell as shown in line 8. In line 9, Dr Chris again

revoiced student 10's response and further elaborated that although bacteria cells have a flagellum, in this case, they were talking about a eukaryotic cell. This incident supports Weir et al.'s (2019) argument that the use of questions and feedback is not only central for stimulating and diagnosing students' thinking or ideas, but they are important for fostering rich dialogue and creating a space where both teachers and learners can analyse their thinking.

Meaning making opportunities resulting from a combination of analogy and gestures and/or actions *[ANLG+G/A]*

The data showed that analogy alongside gesture and/or action was another MMO type that manifested, with the lowest frequency of 2 out of 68. An example of this of type of an MMO occurred in episode 8 of lecture 1 during a whole class discussion where Dr Chris asked the students: "…*what are those bow-looking structures and what do they do*?" Although most students were looking at the projected image on the screen (signalling engagement), they were still unable to respond to this dual question (containing both closed and open aspects). This made Dr Chris realise that his students were struggling to understand the structure and function of the transport vesicle, so he explained using an everyday example that students were familiar which involved a bubble blower and demonstrated how it was used to help his students better understand the structure and functioning of the transport vesicle as shown by **extract B** below.

EXTRACT B

1. *C: "It reminds me from the few days ago when I was walking on the street and there was this person who was blowing out this bubbly substance and …this thing they dipped into some fluid, I mean a ring into some fluid and then they blow, and these bubbles come out and they float into the air (demonstrating to his students how the substance was being blown out). And then I thought, hey these look like those things that my students are going to be tested on…" What are the things there? Those bubble-like things called. Yes!*
2. *S8: We call them transport vesicles (speaking softly).*

After using this analogy Dr Chris then asked his students the question again about what they think those 'bubble-like' things are called, as shown in line 2 of **extract B** above. Student 8 was able to provide a correct response saying that "*We call them transport vesicles*". This incident supports the claim made by Scott and Mortimer (2012) that analogies are essential in science classrooms as they provide learners with a familiar perspective to navigate unfamiliar scientific concepts. Thus, the authors further say that analogies serve as a bridge between students' everyday ways of understanding and scientific ways of understanding the presented content.

5.2.2. Level 2 MMOs that resulted from the combination of two types of SEs

Table 5.1 above shows that the types of MMOs that were classified as level 2 manifested from the combination of three SEs used simultaneously, making them moderate in nature in comparison with the other two categories. The level 2 types of MMOs had a total frequency of 49 out of 129 in Dr Chris' lectures, which included:

1. [LE+ G/A+VR]
2. [Q+G/A+VR]
3. [FDBK+ G/A+VR]

In the following sections I explain and provide instances of how these types of MMOs manifested and how Dr Chris used them to engage his students in his lectures.

MMOs resulting from a combination of gestures and/or actions, visual representations, and lecture explanations *[LE+ G/A+VR]*

Table 5.2 above shows the lecturer's explanation of interacting with gestures and/or actions and visual representation. This SE combination had the highest frequency of 23 out of 49. An example of such a type of MMO manifested in episode 5 of lecture 2, where Dr Chris was recapping the critical concepts that group 5 had mentioned during their presentation about Plasma membranes. Dr Chris began by asking his students "*What is a lipid? Another word for lipids?"*. This was a close-ended question because there was only one correct answer expected, and group 5 had already mentioned the other word for lipid. So, in this instance, the students just needed to demonstrate if they remembered the word. However, the students were not sure about their answers as they were heard murmuring their responses when watching the video. This murmuring was interpreted to mean that although the students were unsure of their answer, they were still engaging with the manifesting MMO. Dr Chris further explained *"They are fats and oils. So, fats and oils are called lipids. This structure shows that there are two sets of lipids and phospholipids, and they have phosphate head which is represented here in grey (Pointing at the slide containing a 3D animal cell) ..."* During Dr Chris' explanation, he pointed at the slide (indicating a gesture and/or action) which contained a colourful and big 3D image of a plasma membrane used by the students during their presentation as shown in Figure 5.4 below.

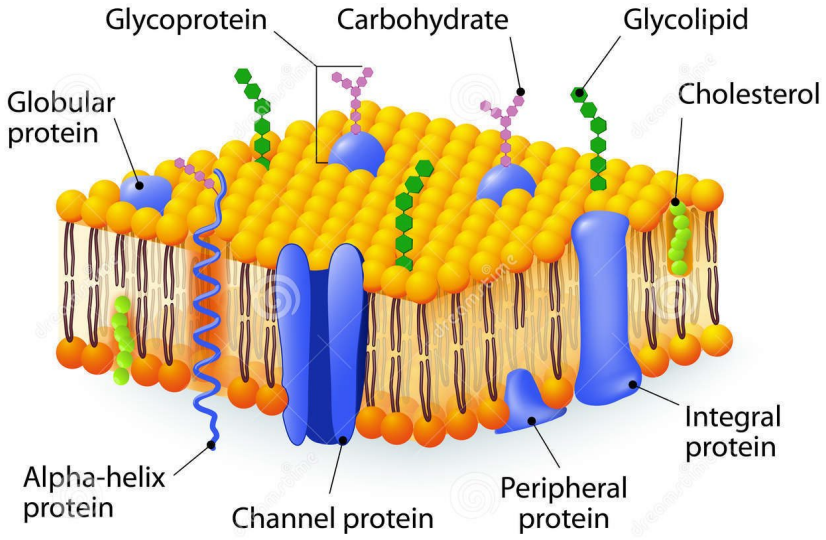


Figure 5.4 Image of a 3D structure of a plasma membrane

Veselinovska et al. (2011) argue that clear and colourful images are powerful visual tools that can involve students in complex biology topics. This was also the case in Dr Chris's lecture as most students were seen looking at the screen in the video recording. The choice of the visual used by the presenting students was interesting to see because it had similar features to the 3D animal cell image that was used by Dr Chris in lecture 1. This might mean that the students found this visual impactful thus integrating it into their presentation. This incident therefore asserts Fischer's (2013) argument that pre-service teachers like newly qualified teachers, often mimic what they find to be 'good' and memorable learning experiences in their early years of their teaching practices. Therefore, highlighting the long-lasting impact that manifesting MMOs have on students' future practice.

MMOs resulting from a combination of questions, gestures and/or actions, and visual representations [Q+G/A+VR]

Table 5.1 above shows that questions, gestures and/or actions, and visual representations were another type of MMO that manifested in Dr Chris' lectures, with the second highest frequency of a total of 13 instances out of 49. This type of MMO manifested in episode 5 of lecture 1 during a whole class discussion about the endoplasmic reticulum (ER). During the episode, Dr Chris asked his students "*What about those that are not there? (Pointing at the organelle on the 3D image of an animal cell on the slide with a laser pointer) they are found somewhere in the Cytoplasm, they are free from the Endoplasm, what are they called?*". This was again a close-ended question given that there is only one specific answer that Dr Chris was expecting from the students. Dr Chris asked this question while pointing at the 3D colourful image of the animal cell which clearly showed the organelles in different

colours. The big and colourful 3D animal cell again attracted students' attention as most were seen looking at the screen in search of the answer and some were heard murmuring their responses (evidencing uncertainty of their responses), which all signalled that they were engaged during this manifesting MMO. This occurrence concurs with Rissanen's (2018) argument that visual representations lay a critical foundation in helping students concretise and start thinking about scientific concepts as well as questions that provide opportunities for them to organise their knowledge in their minds during meaningful learning. Thus, these results show that teacher educators need to constantly incorporate visual aids that will capture and support their students' learning of complex biological structures during MMOs.

MMOs resulting from a combination of feedback, gestures and/or actions, and visual representations [FDBK+ G/A+VR]

Feedback, gestures and/or actions, and visual representations were some of the complex combinations that least manifested in Dr Chris' lectures out of three documented at this level. This type of MMO mainly involved Dr Chris providing feedback based on a visual representation. Such an instance emanated from episode 11 of lecture 1 where Dr Chris and his students had a whole class discussion about the structural differences between animal and plant cells. In the introductory phases of this episode, Dr Chris began by showing the students a simple 2D microscopic image of a plant cell as shown in Figure 5.5 below.

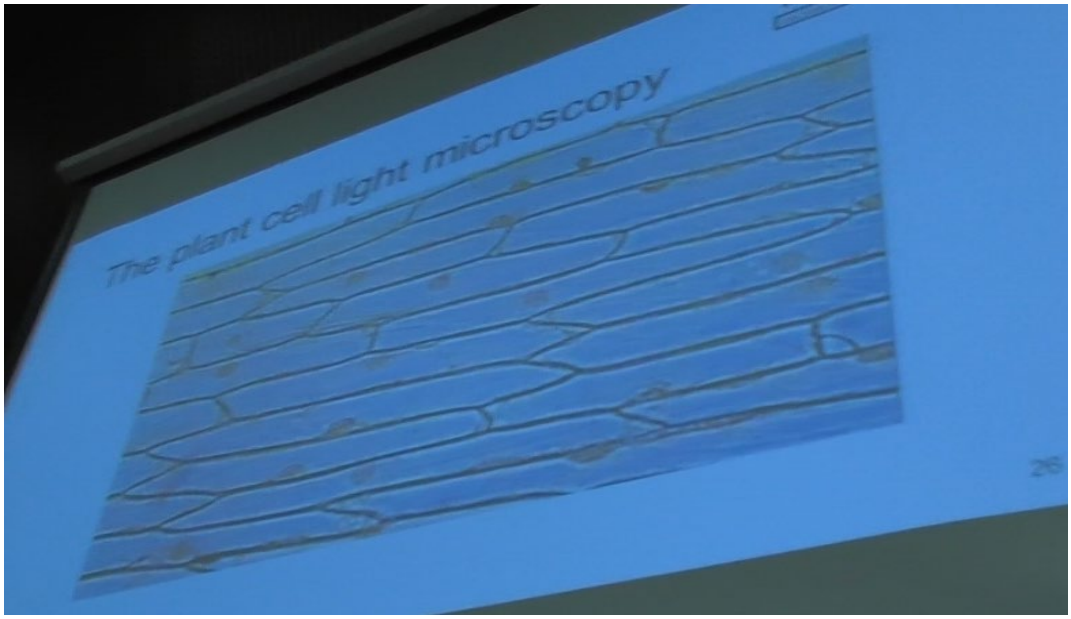


Figure 5.5. 2D image of a plant cell under a microscope

Before asking a question about the notable structural differences that the students could point out between the plant and animal cell, Dr Chris projected another colourful and labelled 3D image of a plant cell as shown in Figure 5.6 below.

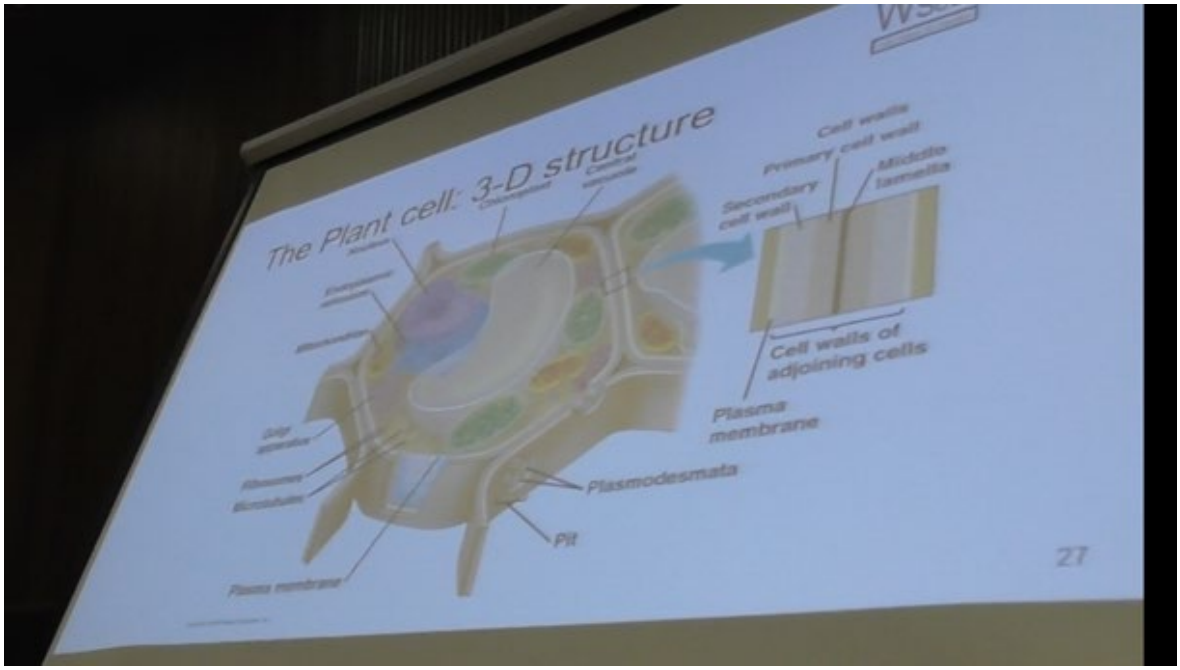


Figure 5.6 3D image of a plant cell

This became of interest during the VSRI as to why Dr Chris opted to use a 3D image of a plant cell to stimulate the whole class discussion, instead of a 2D, and he mentioned:

"I want my students to be exposed to the organelles using different types of visual representations, whether 2D or 3D. I also want them to learn to interpret these different visuals and understand the limitations of 2D because they are going to be teachers, so I am sharing this skill with them to also share with their future students. And I want them to see the importance of using vibrant 3D images to help them see and communicate the structures and function of the cell."

Dr Chris's response shows that he was aware of the importance of exposing his students to different visual representations and the challenges that are linked to just using plain visual representations for engagement purposes. According to Gibbens (2022), many biology lecturers often underestimate the use of colourful visuals as strategies for fostering student engagement and for promoting appreciation and value of cell biology in their students' everyday lives. This was the case in Dr Chris's lectures as the colourful visuals were successfully used to engage the students, and this was as evidenced by them looking at the screen again and some raising their hands. Student 12 mentioned that one of the differences is that "*It contains a double membrane.*". Dr Chris then provided feedback by saying "*It contains a double membrane* while he pointed (signalling a gesture and/or action) at the double membrane that student 12 was referring to. This type of feedback is what Adcroft (2011) calls re-voiced

feedback and is usually used in large classroom contexts as a means of not only re-affirming students' responses but for making the response accessible to all the students, especially in large classroom venues. Ferris (2014) says that teacher revoicing which involves teachers repeating and emphasising the key statements or concepts that their students mentioned in their response is an important teaching and learning strategy. Re-voicing often shows students how valuable their responses are in the development and continuation of the learning process, as in the case with Dr Chris. This finding highlights the need for teacher educators to engage with their students' responses during feedback, especially in large lecture venues to foster collaborative learning during manifesting MMOs.

5.2.3. Level 3 MMOs that resulted from the combination of three types of SEs

Deducing from Table 5.1 above, reveals that the types of MMOs classified at level 3 were characterised by the combination of four SEs used simultaneously, making them more complex in nature in comparison with the other two categories. The data table revealed that the three types of MMOs manifest in Dr Chris' lectures which included:

- Lecture explanations+ writing+ gestures and/or actions and visual representation [LE+WRTN+G/A+VR]
- Lecture explanations+ question+ gestures and/or actions and visual representation [LE+Q+G/A+VR]
- Feedback + question + gestures and/or actions and visual representation [FDBK] +Q+G/A+VR]

In the sections below I further explain and provide instances of how these types of MMOs manifested and how Dr Chris used them to engage his students in his lectures.

MMOs resulting from a combination of lecture explanation+ writing/drawing+ gestures and/or actions and visual representation [LE+WRTN+G/A+VR]

Table 5.2 above revealed that lecturer explanations alongside writing, gestures and/or actions and visual representation **[LE+WRTN+G/A+VR]** were one of the manifesting MMO types in Dr Chris' lectures at this level. This was a notable combination because it was the only MMO type that included the SE of drawing and/or writing unlike the other types of MMOs that manifested in Dr Chris' lectures. These results support the findings of a study that was conducted by Halliday and Martin (2003), which found out that most lecturers although they realise the importance of writing and drawing as a tool for decoding scientific meanings, but they still neglect it and resort to mostly over-explaining and theorising concepts. Although there were a few MMOs that involved Dr Chris writing and drawing while explaining and demonstrating using a visual, but he did not over-explain the concepts but also wrote, drew, and pointed at the critical aspects of the drawing or text during an explanation. This was exemplified in episode 3 of lecture 2 after group 2's presentation which was based on the structure and function of microtubules. During the episode, Dr Chris was interested in explaining and

elaborating on the structure and function of microtubules as this concept was not mentioned in greater detail by group 2 members. So, Dr Chris began by spelling out the word 'dynein' (talk) while writing (a type of SE) on the piece of paper that was projected (a visual representation). According to Ferreira (2010), pronunciation of unfamiliar biology terminology is one of the major obstacles that inhibit student engagement as they find it 'foreign'. This illustrates that Dr Chris paid attention to developing his students' understanding of the terminology associated with learning cell biology, as he broke down the term into its constituents. Dr Chris did this by explaining to the students that the word "*Di*" as it is sometimes pronounced by others, means "two". He further explained that is because '*the structure is made up of two proteins.'* Postman (1979) argues that when a lecturer breaks down a scientific term to its constituents, they are strengthening and developing their students' scientific vocabulary.

Dr Chris further explained to his students that the structure of the microtubules is in spiral form while he drew (type of SE) the spiral shape arrangements of the dynein arms as demonstrated by Figure 5.7 below.

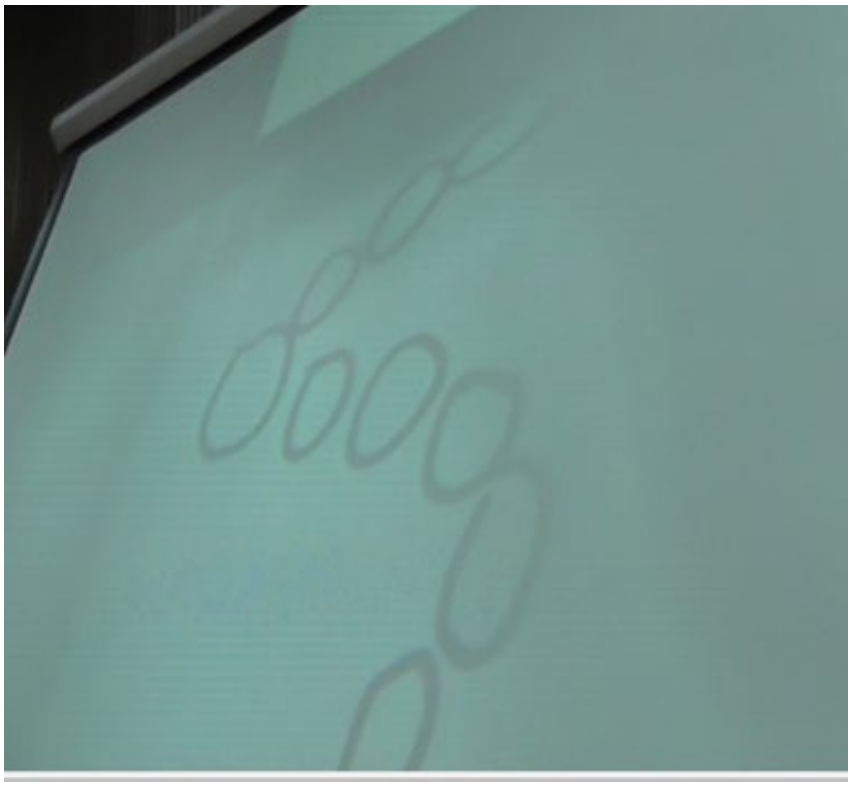


Figure 5.7 Spiral drawing representing the arrangement of the structure of dynein arms

While using a 2D drawing (a visual representation), Dr Chris continued to explain to his students that he would like them to take note of the spiral arrangement of the structure of dynein arms. This disputes

the claim made by Fernández and Tejada (2018) that lecturers do not place much emphasis on the structure and function of organelles when teaching the topic, as this was not the case in Dr Chris' lecture. Dr Chris stressed the importance of his students understanding the structure of the dynein arms. Generally, this type of MMO provided students with an opportunity to assess, filter and comprehend the important concepts to grasp during the explanation (Dukhan et al., 2019; Havita, 2000). Most students in the video were seen making notes for themselves, which serves as evidence that this manifesting MMO engaged them.

To further engage the students with the manifesting MMO, Dr Chris also made notes of all the important aspects that he mentioned during his explanation he pointed (indicating a gesture or action) at some of the concepts as shown in Figure 5.8 below.

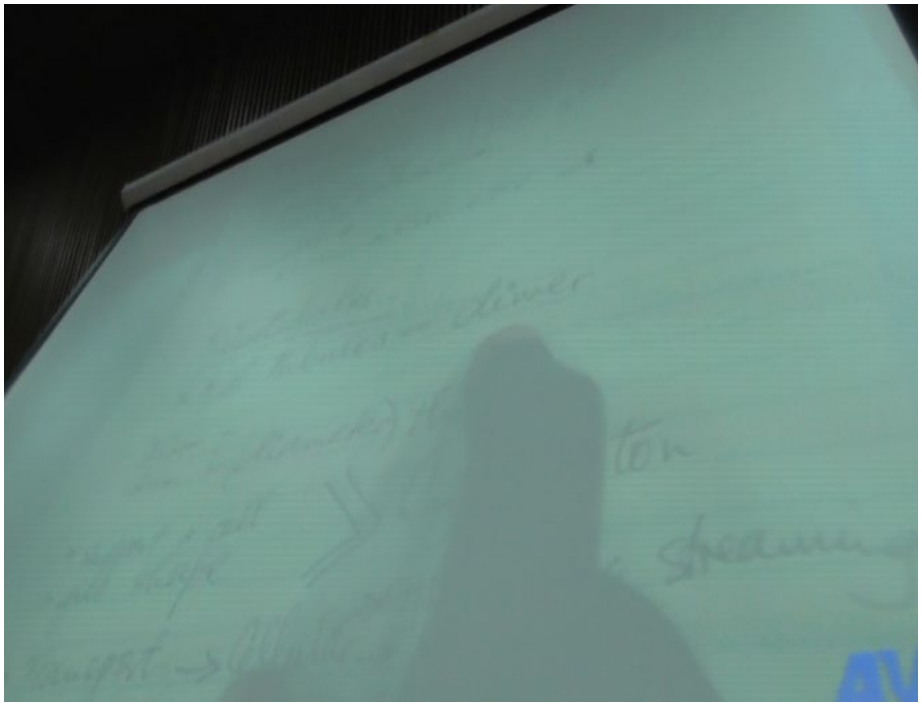


Figure 5.8 Dr Chris pointing to one of the concepts he had written on the data projector.

This insight highlights the dual importance for teacher educators to focus on promoting MMOs that not only enhance students' understanding of the structure and function of a given topic but also foster a deep, fundamental grasp of the content. This observation recognises that while surface-level comprehension of factual content is valuable during manifesting MMOs, effective teaching must balance this with the development of conceptual depth. By doing so, educators ensure students are not just learning isolated facts but can integrate and apply their knowledge in meaningful ways, leading to a more comprehensive and lasting understanding.

MMOs resulting from a combination of feedback + question + gestures and/or actions and visual representation [FDBK] +Q+G/A+VR]

Feedback, alongside questions, gestures and/or actions, and visual representation, appeared most frequently in the observed MMOs, occurring 5 out of 12 times. One such example manifested in episode 4 of lecture 2 when Dr Chris provided feedback on a group presentation about cytosol. He began the class discussion by praising the group's insightful presentation on the structure of cytosol and, using one of their visual representations which he pointed at (a gesture and/or action) as he simultaneously asked the closed-ended question: '*What is the structure of cytosol?'* However, there was no immediate response, and many students on the video appeared confused. This confusion likely stemmed from the nature of the question, as '*What is the structure of cytosol?'* is problematic. The cytosol is not a structured organelle like the nucleus or mitochondria; rather, it is the fluid component of the cytoplasm in which organelles are suspended, and it does not have a distinct structure. Despite Dr Chris repeating the question, it appeared to remain unclear to the students. One student hesitantly responded that cytosol is 'water-like,' a point that had been emphasised in the group's presentation. This incident highlights the importance of clear and precise phrasing of questions, as unclear questions can impede the manifestation of MMOs. This instance highlights the value of MMOs involving group presentations in fostering peer learning, as they encourage students to engage with and reflect on content presented by their peers, which is beneficial in biology lectures.

MMOs resulting from a combination of lecture explanations+ questions + gestures and/or actions and visual representation [LE+Q+G/A+VR]

Lecture explanations alongside questions, gestures and/or actions and visual representation had the lowest of 2 out of 12 in Dr Chris's lectures. This MMO type involved Dr Chris explaining while asking questions based on a visual aid that he constantly pointed to. This type of MMO was observed in lecture 1 episode 2 where Dr Chris, after the students had completed their 2D drawings, had to engage in an open discussion of the different animal cells. Before they could be discussed, Dr Chris explained the importance of why they had to make these drawings as captured in **extract C** below.

Extract C

1.	C: *The animal cell has several organelles. And for it to help you, and I am not saying memorise it, that's why I asked you to make a drawing of an animal cell. I would like you to take note of how it has been labelled. We were talking about labelling the other day and someone told us that labels need to be flat, they are supposed to be horizontal and you can notice that all the labels come out from the drawing to one side (Pointing to the image on the slide) and you will also notice that the labels are outside the diagrams (Pointing at the outside of the diagram using a laser pointer). Is that clear to all of you? They are horizontal and outside and the guidelines are straight, even though the pointer may not be at right angle, but they are not bent, they are straight. They didn't use freehand to do that, they used a straight edge for the guidelines. These are the skills that we would like you to develop, and we would like you to share with your learners as you go out there after many years. Although they may be difficult to learn, I would like you to see that when you look at the cell you can start from the center or you can start from the outside in order to understand, in order to learn about the parts…. So, what do you find in the innermost of the cell (pointing at the*

slide at image on the slide)? What is the name of the organelles that are most inner or most inside? (Rephrases questions) innermost part of the cell?

From the extract, it can be deduced that Dr Chris began by explaining to the students, using a visual aid (a projected 3D image of the cell), that the purpose of engaging them previously in the 2D cell activity was to ensure a thorough understanding of the various animal cell organelles rather than merely memorising them. This aligns with Bartoszeck and Tunnicliffe's (2017) assertion that drawing is a fundamental tool for learning, as it serves as a metacognitive strategy that enables students to reflect on their thinking and deepen their understanding of the concepts that they are engaging with during the lecture.

During the VSRIs when Dr Chris' was asked why he used this activity mentioned that:

"…*This is a skill that is often ignored at schools, and you will find that most of the students finish high school, but they cannot even draw and do not even know the importance of having biological skills needed as future teachers*…"

Dr Chris' response revealed an awareness of his students' identities as future educators as well as some of the knowledge gaps that they might have when engaging with the topic. Highlighting this knowledge is important in shaping the type of MMOs that manifest during lectures.

During the episode, Dr Chris asked a closed-ended question about the organ located in the innermost part of the cell, while still pointing or referencing the projected 3D visual representation of the animal cell. The student forms of engagements varied, some were looking directly at Dr Chris, signalling listening; others had their hands raised, ready to answer; while others were focused on the screen, likely engaging further with the visual to formulate a correct response. These diverse forms of engagements could be interpreted to mean that the students were actively engaged during the manifesting MMO. These results, therefore, highlights the value of drawing and visual activities, as these seem to engage students beyond route memorisation of the biology concepts. Therefore, biology lecturers should promote MMOs that involve drawing activities to allow students to interact with biological content in ways that foster both metacognition and conceptual understanding.

5.3. Discussion of the analysis and Conclusion(s)

This chapter presented an analysis of data from Dr Chris, the first case. The analysis identified eleven distinct types of MMOs, which manifested from combinations of four social exchanges (SEs) which involved talk, visual representations, gestures and/or actions, and writing and/or drawing. These MMOs were categorised into three levels of complexity, as outlined in Chapter 4. The analysis shows that majority of MMOs manifested at level 1 in Dr Chris' lectures and they predominantly engaged students

who preferred to learn visually and auditory, as most of the MMOs in this level included a component of either a visual aid, question or lecturer explanation.

Although Dr Chris frequently used closed-ended questions to promote engagement, the effectiveness of these MMOs seemed to be heavily influenced by the clarity of the questions. In other words, properly phrased questions appeared to stimulate critical thinking and active participation. However, ambiguities in phrasing such questions occasionally led to confusion and missed opportunities for engagement. Thus, emphasising the critical need for planning and thoughtfully phrasing questions to foster effective student engagement with manifesting MMOs.

Level 2 MMOs, which were moderate in complexity, often featured visual representations such as 2D and 3D models as well as drawings. These visual representations seemed to play an instrumental role in capturing students' attention and possibly aiding their understanding of abstract and complex biological structures. Drawing activities appeared to serve as powerful tools for reflection and comprehension, encouraging students to engage in MMOs aimed to deepen their conceptual grasp of the material. The integration of these visual representations with explanations, feedback, gestures, and questions also seemed to enhance student engagement and provided them with skills applicable to their future roles as biology teacher educators.

The analysis also suggests that the success of MMOs depended significantly on the biology lecturer's responsiveness to students' needs. Lecturers recognised these needs during lectures through students' verbal responses, hesitations, mispronunciations, incomplete explanations, or even non-verbal cues such as confusion, silence, or incorrect representations when drawing 2D scientific structures. For example, by noticing students' difficulties in drawing or pronouncing scientific terminology, Dr Chris adapted his instruction to make MMOs more accessible and inclusive. This responsiveness points to the importance of lecturers' knowledge of their students in the manifestation of MMOs during lectures. Importantly, this knowledge is not generic but closely tied to their TSPCK, that is, their ability to anticipate and interpret common student challenges in particular biology concepts, and to design or adjust SEs accordingly. The analysis revealed that when lecturers draw on such knowledge, they are better positioned to tailor SEs that manifest as MMOs, which not only enhance student engagement but also contribute to the development of critical disciplinary skills. In this way, the lecturer's awareness of students' needs, coupled with their TSPCK, ensures that MMOs place students at the centre of their learning.

Although Level 3 MMOs shared the same number of SE combinations as Level 2, they were set apart by their level of complexity and foundational use of gestures and/or actions. This SE was present in all Level 3 MMOs that manifested in Dr Chris' lectures and might have been strategically used to convey information to all students, including those seated at the back of the lecture hall, who might have

struggled to see the screen. Dr Chris also used actions and/or gestures to include humour during the manifesting MMOs, which appeared to be valuable for fostering a positive teaching and learning atmosphere, especially in addressing cell biology concepts, which students often find difficult and/or boring. These findings emphasise the importance of gestures and/or action, humour and the role of a constructivism as a teaching philosophy that could foster the manifestation of MMOs that are aimed at enhancing student engagement and creating an inclusive learning environment, especially in large venues.

Finally, the analysis highlighted the pivotal role of engaging students in MMOs that involved them in group activities and/or peer presentations, complemented by lecturer feedback, in fostering collaborative engagement. Such MMOs that included such activities seem to encourage students to reflect on their peers' perspectives, facilitate dialogue and shared learning experiences. The lecturer's feedback seemed to further enrich these MMOs by validating students' contributions and fostering a deeper engagement with the key concepts covered in the lecture.

In the next chapter, the analysis will turn to Dr Molly's lectures, exploring the manifestation of MMOs in her lecturing of mitosis and animal tissues to third-year biology students.

Chapter 6

Case 2: Dr Molly

Topics: mitosis and animal tissue

Class: 3rd Year biology pre-service teachers

6.0. Introduction

The previous chapter introduced Dr Chris' case who was observed teaching cell biology to 1st year students. This chapter begins by presenting Dr Molly's background information as a means of contextualising the findings. It is important to mention that the same data analysis processes detailed in Chapters 3 and 4 were applied to Dr Molly's case. The chapter provides an overview of the topics, and the challenges associated with their teaching and learning. To conclude the chapter, I provided insights aligned with the research questions that guided this study.

6.1. Dr Molly's background information and lecture overview

Table 6.1 below presents a summary of Dr Molly's background information and an overview of the lectures that she was observed lecturing as a means of contextualising the results of this study. The information presented in Table 6.1 below was further elaborated upon in the subsequent sub-sections.

Table 6.1. Dr Molly's background and lecture information

Race/age/experience	Qualification/s held	Teaching Philosophy	Class taught	Duration of the lectures/ minute		Number of PSTs taught	Content taught
				Lecture 1	Lecture 2		
African female. aged 55+ years, with more than 30 years of teaching experience	B.Ed., BSc Hons, MSc Ed, PhD	PCK, and Constructivism (particularly cognitive and social constructivism)	3rd-year biology PSTs	47	21	33 instead of 86	Mitosis in Animal tissues

6.1.1 Content overview and general challenges associated with teaching mitosis and animal tissues

As earlier stated, Dr Molly was observed presenting the topics of mitosis and animal tissues. In lecture 1, Dr Molly taught the topic of mitosis which is the study of the events of a cell cycle that lead to the

production of two identical nuclei. According to Reece et al. (2018), mitosis is a vital process of cell division in eukaryotic organisms, enabling life processing such as growth, repair, and reproduction to mention a few. Mitosis is part of the broader cell cycle, which includes interphase which involves DNA replication (Reece et al., 2018). Campbell and Reece (2005) states that interphase is a critical preparatory phase of the cell cycle, accounting for about 90% of its duration. Reece et al. (2018) further explain that interphase is subdivided into three distinct stages which involve:

1. **Growth (G1) Phase (First Gap)**:
    - The cell undergoes significant growth, producing proteins and organelles.
    - It performs its normal functions while preparing the necessary building blocks for DNA replication.
2. **Synthesis (S) Phase**:
    - DNA replication occurs, which will result in the formation of two chromosomes during mitosis.
    - Each chromosome will consist of two sister chromatids connected by a centromere.
3. **Growth (G2) Phase (Second Gap)**:
    - The cell continues to grow and produces additional proteins and organelles.
    - It also ensures that the DNA has been correctly replicated and begins forming the structures (like spindle fibres) required for mitosis.

During interphase, the cell is metabolically active, growing in size, and preparing for division, but chromosomes are not yet visible under a microscope because they remain in their relaxed chromatin form (Reece et al.,2018; Shen, 2020). This meticulous preparation ensures the accuracy of the subsequent mitotic phase. Shen (2020) say that mitosis is characterised by four distinct phases namely:

1. **Prophase**: Chromatin condenses into chromosomes, become visible and each chromosome seen to be made up of two chromatids, and the nuclear envelope disintegrates. Spindle fibres start forming.
2. **Metaphase**: Chromosomes align at the cell's equatorial plane, attached to spindle fibres.
3. **Anaphase**: Sister chromatids separate and are pulled to opposite poles of the cell.
4. **Telophase**: Nuclear envelopes reform around the separated chromosomes, and the cell begins to split.

Telophase is followed by cytokinesis where the cytoplasm splits into two halves resulting in two daughter cells containing an equal number of chromosomes, thus mitosis is known as a multiplication division (Reece et al.,2018). In animal cells, the cytoplasm divides by forming a cleavage furrow. While, in plant cells, a cell plate forms, eventually developing into a cell wall (Reece et al.,2018; Shen, 2020).

In lecture 2, Dr Molly was observed presenting the sub-topic of animal tissues. A tissue is made up of a group of specialised cells that work together to perform a specific function (Campbell & Reece, 2005; Shen, 2020). Therefore, the study of animal tissues involves the exploration of a group of animal cells that have similar structures that work together as a unit to perform specialised functions (Reece et al.,2018). The study of animal tissues also examines the different relationships that exist amongst these specialised tissues. According to Reece et al. (2018) and Shen (2020) animal tissues are mainly classified into four basic types. The first type is **epithelial** tissue which covers the outside of the body and line organs and cavities within the body such as the nasal passages which is crucial for the sense of smell. The second type is **connective** tissue consisting of a sparse population of cells scattered through an extracellular matrix that holds many tissues and organs together and in place e.g. cartilage. The third type is **nervous** tissue which is important in receiving, processing, and transmission of information throughout the body. It consists mainly of **neurons,** which are responsible for transmitting nerve impulses, and glia, which insulates and support the neurons. The last one is **muscle** tissue, which is essential for movement (both voluntary and involuntary), posture maintenance, and overall bodily functions.

Like cell biology, these two topics are also considered to be difficult topics to teach and learn because of the challenges related to their complex terminology and the abstract nature in which the concepts are taught to students, often taught theoretically without any visual aids (Öztap et al., 2016; Yip,1998). Another challenge is that students often confuse mitosis with meiosis because of the similar stages involved in both processes. Thus, Thörne and Gericke (2013) suggest that teachers need to clearly state the differences between these two processes to their students to foster conceptual understanding.

6.1.2. Context of the lecture, resources and technologies used by Dr Molly

Dr Molly was observed lecturing mitosis and animal tissues to a group of 3rd years. These 3rd years had completed two full years of natural science lectures and were now biology majors. It is important to mention that when Dr Molly was observed during these two lectures, student disruptions were happening at SAX. Unfortunately, this negatively impacted students' attendance and the duration of the lectures. During this time, most classes were cancelled throughout the campus, and most students were not sure if these classes would take place. As a result, both lectures were short as shown in Table 6.1 above. What is also worth mentioning is that during this lecture, Dr Molly experienced technical glitches where the data projector would suddenly stop projecting necessitating explanations of the content without the aid of visuals. This resulted in some students complaining to Dr Molly after the lecture that they had difficulties differentiating between telophase and cytokinesis as well as chromosomes and chromatids, which are two commonly known difficulties that most literature on cell division have been reported on (see: Öztap et al., 2016; Thörne, 2012). So, in lecture 2, Dr Molly began by first addressing these issues and spent more time trying to clarify the differences between chromosomes and chromatids

as her students were grappling with the concepts before moving along to present the planned content on animal tissues. This all happened even though lecture 2 only had a duration of 21 minutes as shown by Table 6.1 above instead of the normal allocated 45 minutes duration of a single period at SAX.

The physical environment of the lecture venue further impacted Dr Molly's ability to manage the class. The venue had closely spaced, ascending rows, which restricted her movement during the lectures as depicted in Figure 6.1 below.



Figure 6.1 Layout of Dr Molly's lecture venue

Dr. Molly's lecture layout confined her to the front area of the lecture venue. This lack of mobility made it difficult for her to engage with students seated at the back, consequently, many of whom were observed talking and disengaging from the lecture. Dr Molly often had to reprimand these students as observed in the lecture observation videos.

In terms of resources and technology, Dr Molly used prepared presentation slides that featured colourful 2D representations of mitosis phases and animal tissues. She used a metal rod to point at images to help focus her students' attention. The lectures were supported by a data projector and a single screen at the front of the room, which all students could view. Additionally, Dr Molly posted slides and other learning materials, including assignment instructions and tutorials, on the school's Learning Management System (LMS) called Sakai.

6.2. Presenting the findings

Table 6.2 shows the manifestation of fourteen different MMO types across three levels in Dr Molly's two lectures, with a combined total frequency of 170. Of these fourteen MMO types, nine were at level 1, with a total frequency of 124 out of 170. Level 2 contained three MMO types, which manifested with a frequency of 36 out of 170. Additionally, there were two level 3 MMO types that appeared with a total frequency of 10 out of 170. These results indicated that most MMOs that manifested in Dr Molly's lectures were mostly classified at level 1, catering primarily to students with one or two learning preferences across the two lectures. Moreover, only two complex MMO types manifested across her two lectures which were capable of engaging students with all four learning preferences simultaneously. In the sub-section below, I further analysed how these MMOs manifested during Dr Molly's lectures and evaluated their effectiveness in engaging students.

Table 6.2 Summarised findings of the types of SEs and MMOs that manifested across the three levels in Dr Molly's lectures

Levels of MMOs	Description of each level	Types of MMOs manifesting across the two lectures	Frequency of type of MMO across lectures	Manifesting forms of engagement across the two lectures
1	**Combination of two types of SEs**	1 Q+ FDBK	**15**	**-Some students** are looking at the **screen** **-Some students** have their **hands raised** and are **answering questions** and **some asking questions** **-A few students** are **writing notes** **-Some students** are listening to the lecturer **while a few** are **disengaged-talking** to their friends **- Most students** are seen **laughing** **-Some students** are seen **drawing** while some are **looking at the board**
		2.LE+Q	**23**	
		3. LE+G/A]	**12**	
		4. LE+VR	**6**	
		5. MNMC+Q	**2**	
		6. G/A+Q	**21**	
		7. G/A+FDBK	**13**	
		8. LE+FDBK	**10**	
		9. VR+Q	**22**	
		Proportion of the total frequency of MMOs	**124**	
		Proportion of the total (in %)	**73**	
2	**Combination of three types of SEs**	1.G/A+Q+ VR	**13**	**-Some students** are seen **talking with their peers** **-Most students** are seen **looking at the screen** **-Most students** have **their hands** raised and **answering questions** -A **few students** are **asking questions** **-A few students** are **seen making notes** **-Most students** are **seen listening while** some students are **disengaged-looking elsewhere while some are talking to their friends** **-Most students are seen laughing**
		2.GA+VR+LE	**17**	
		3. LE+ Q+ANLG	**6**	
		Proportion of the total frequency of MMOs	**36**	
		Proportion of the total in (%)	**21**	

3	**Combination of four types of SEs**	[LE+ G/A+VR+[Q]	**6**	-A student is seen drawing on the board -**Most** students are seen looking at the screen -**Most** students have their hands raised and answer questions and some ask questions -A **few** students are seen writing or making notes -**Most** students are seen laughing -**Most** students are seen listening -**Some** students are disengaged-looking elsewhere while -**Some** are talking to their friends
		[FDBK + LE+ G/A + VR]	**4**	
		Proportion of the total frequency of MMOs	**10**	
		Proportion of the total in (%)	**6**	

6.2.1. Level 1 MMOs that result from the combination of two types of SEs

Table 6.2 above reveals that there were more level 1MMO types that manifested in Dr Molly's lectures compared to the other two levels, with a total frequency of 124 out of 170 across the two lectures. Table 6.2 further shows that the nine level 1 MMO types manifested in Dr Molly's lectures involved:

1. A lecture explanation and question [LE+Q]
2. A visual representation and a question [VR+Q]
3. A gesture and/or action and question [G/A+Q]
4. Feedback and question [Q+ FDBK]
5. A gesture and/or action and feedback [G/A+ FDBK]
6. Lecture explanations and gesture and/or action [LE+G/A]
7. A lecture explanation and feedback [LE+ FDBK]
8. A lecture explanation and visual representation [LE+ VR]
9. A mnemonic and question [MNM+Q]

Out of the total of the nine types of MMO that manifested in Dr Molly's lectures, three SE combinations were not observed in the previous case. This means that there was a higher manifestation of MMOs in Dr Molly's lectures that were most **likely to engage students with one or two learning preferences** as in the previous case. In the sub-sections below, I explain and provide incidences of how these SE novel combinations led to the manifestation of MMOs in her two lectures.

MMOs resulting from a combination of lecturer explanations and questions [LE+Q]

Lecturer explanations and questions were one of the SE combinations that had the highest frequency of 23 out of 124 across the two lectures that Dr Molly was observed lecturing. This type of MMO was characterised by occurrences where Dr Molly explained following with a question. An example of such an incident occurred in episode 7 of lecture 2 where Dr Molly and her students were discussing the location of connective tissues. The students had previously provided different responses to where they thought connective tissues were found in the human body. Dr Molly explained that "*...this is the type of the tissue found in the cartilage, joints, ligaments, skin…Connective tissues are important for providing strength and support, reducing friction, and act as shock absorbers…* During this explanation, some students were seen looking at Dr Molly whilst some students were seen jotting down notes in the video as exemplified by Figure 6.1 above, which signified that this MMO did engage the

students. While explaining, Dr Molly asked an open-ended question and said, "*Can you give other examples where connective tissues can be found in the body?*" The students provided a few examples including skin, blood vessels, knees and elbows to mention a few. This incident showed that Dr Molly was able to activate students' prior knowledge about the concept presented during the MMO. Given that students were prompted to discuss and think more about the presented content in relation to their prior knowledge, further supports the claim that this incident led to engagement that could foster deep meaningful learning (Dolmans et al., 2016).

MMOs resulting from a combination of visual representations and questions [VR+Q]

The findings of this study as tabulated in 6.2 above illustrate that visual representations alongside questions were the second highest type of SE combination that Dr Molly used at this level to promote the manifestation of MMOs, with a total frequency of 22 out of 124 in both lectures. Such an MMO type resulted when Dr Molly asked a question based on visual representation. An example of such a case where this type of MMO manifested was in episode 2 of lecture 2. During this episode, Dr Molly and her students were engaged in a whole class discussion where they were trying to differentiate between a chromatid and a chromosome. One of the students noted that their misconception of the two organelles emanates from how they are represented in the textbooks. So, before asking the question, Dr Molly explained to the student that there is nothing wrong with how the two structures are represented in the textbooks. Dr Molly then asked the students a question, saying "*But let's use our brains, looking at the anaphase image (without pointing at the image) those two separates, do you agree that the two sister chromatids separate in anaphase?*". Dr Molly's question required a yes or no answer from the students, showing that it was a closed-ended question that required them to deduce meaning from the 2D animated colourful image shown in Figure 6.2 below.



Figure 6.2. 2D animated image showing anaphase

In the video, some students demonstrated engagement by focusing on the screen, seemingly captivated by the animated visual that depicted the separation of homologous chromosomes into independent ones

during anaphase. Simultaneously, other students had their hands raised, also signalling active involvement and engagement during the manifesting MMO. As a result, students were then able to provide an answer in unison saying "*Yes*". This incident thus supports Nocek's (2021) argument that 'vibrant' multimedia such as animated visual representations are important tools in biology as they help students to be able to better unpack and formulate scientific meanings during teaching and learning. According to Nocek (2021), such multimedia is crucial in providing students with insights into the microscopic biological processes in a way that traditional lecturing and static graphics cannot. Thus, biology lecturers are encouraged to use various visual representations including animated ones to promote MMOs that help students better understand microscopic processes during lectures.

MMOs resulting from a combination of questions, gestures and/or actions [Q+G/A]

Questions alongside gestures and/or actions were the third highest SE combination that Dr Molly used to promote MMOs in this level, with a total frequency of 21 out of 124 across the two lectures. This MMO type was characterised by occurrences where Dr Molly asked a question while simultaneously using bodily gestures and/or actions. Such an instance manifested in episode 5 of lecture 2 where Dr Molly and her students were engaged in a whole class discussion about muscle tissues. During their discussion, Dr Molly asked her students the following close-ended question "*Do we have muscles here?* While asking the question, Dr Molly pointed at her chin to show the students exactly the part of the body that she referring to. As Dr Molly pointed at her chin some students were looking at her while a few were murmuring which evidenced that these students were engaged in this type of MMO. Although Dr Molly asked a closed-ended question which again required a yes or no answer, the students did not provide any direct response. However, a few students were murmuring signalling that they were not entirely sure of their responses. So, rather than missing this opportunity by simply giving the students the answer, Dr Molly then decided to re-phrase the question and asked *"Okay, let me rather ask where we find muscle tissue?"* This time although the question was still a closed-ended question it now required a more elaborative response. Student 5 then responded by saying "*You find the muscles over the skeleton."* This occurrence validates Tanner's (2023) views that questions are key strategies that teachers can use to assess their students' prior knowledge of concepts during a lecture and can provide them with an indication as to how best they can adjust their teaching strategies to meet their students' learning needs as well as their desired lecture outcomes.

Furthermore, this instance revealed that this revised MMO not only engaged students verbally and visually but also enabled her to access her their prior knowledge and understanding of the location of muscle tissues. Vygotsky (1978) argued that when a teacher shows interest in probing students' prior ideas, it is an indication that their teaching practices are underpinned by the constructivist approach which was the case with Dr Molly who did mention that this approach underpins her teaching

philosophy. Therefore, highlighting that the lecturer's teaching philosophies seem to impact or shape the manifesting MMOs in their lectures.

MMOs resulting from a combination of questions and feedback [Q+ FDBK]

The data revealed that question and feedback were the fourth highest SE combination that manifested in Dr Molly's lectures at this level, with a total frequency of 15 of 129 across the two lectures. This MMO was characterised by events where Dr Molly asked a question based on feedback provided to the students. An example of this type of MMO resulted in episode 2 of lecture 1 where there was a whole class discussion based on the explanation of the cell cycle. During this instance, Dr Molly began by asking the students a question about the type of genetic material found in the nucleus just before cell replication and the students provided various answers, which signalled their engagement in the manifesting MMOs. One of the students mentioned that the genetic material was in a form of DNA. Dr Molly then provided them with feedback by saying "*Okay, now that we agree that we find genetic material in a form of DNA…".* This type of interaction is what Wood et al. (2018) characterise as an Initiation-response-feedback (IRF) pattern of discourse between the teacher and learner. Dr Molly's feedback revealed that she agreed with the students' presented ideas, suggesting an exchange of information between her and the students during this manifesting MMO. This exchange of information is one of the key benefits that Wood et al. (2018) associate with the IRF type of interaction. Contrary to that view, Wood et al. (2018) argue that IRF interactions are often rigid and are often used by teachers to arrive at one correct answer rather than promoting in-depth as well as 'authentic' discussions. This was the case in this incident, as Dr Molly was looking for only one correct answer as reflected in her feedback. Scott and Mortimer (2012) classify such interactions as dialogic authoritative, where the lecturer controls the dialogue and decides when to give students a chance to speak, and which answers are correct, and which are not. Despite that being the case, it can be said that this MMO engaged the students, particularly those who prefer to learn auditorily.

MMOs resulting from a combination of a gesture and/or action and feedback [G/A+FDBK]

Table 6.2 above indicates that gestures and/or actions alongside feedback were the fifth highest SE combinations out of the nine in Dr Molly's lectures at this level. This MMO type had a total frequency of 13 out of 129 across the two lectures. This MMO type was exemplified where Dr Molly would use a gesture and/or action while providing feedback. Such an instance manifested in episode 2 of lecture 1, where there was a whole class discussion based on defining the cell cycle. During this episode, Dr Molly began by initiating the discussion with the following open-ended question "*Right, what do you understand by cell cycle before I tell you what it is?* Again, the question asked by Dr Molly provided further evidence that her two teaching philosophies (PCK and constructivism) guided the type of MMO that manifested in her lectures. This is taking into consideration that Dr Molly clearly mentioned that she did not want to give the students the answer but wanted to hear their prior ideas first. This meant

that she was again more interested in eliciting her students' prior knowledge about their understanding of the cell cycle rather than telling them the correct answer from the onset. This result suggested that Dr Molly made attempts to foster active and self-directed learning (components of constructivism) where students are continuously thinking about the introduced concepts and building from their ideas as the lecture progresses.

Although only a few students raised their hands as seen in the video, it signalled that this MMO engaged some of them. Student 5 responded by saying that the "*Cell cycle is the process whereby the cell divides to produce an identical copy of itself."* Dr Molly provided student 5 with feedback by saying *"Correct that is very good, the cell divides, thank you*" while demonstrating the division process with her hands as shown in Figure 5.3 below. This interaction was regarded as a dialogic-authoritative discourse given that Dr Molly was in control of the discussion.



Figure 6.3 Dr Molly demonstrates cells dividing using her hands

Öztap et al. (2016) says that any demonstrations whether in the form of pictures, models, or gestures are important in helping students differentiate commonly confused terms such as cell division and cell cycle. This result could suggest that Dr Molly might have been aware of this issue thus emphasising the word cell division through gestures. During this incident, most students in the video were seen looking at Dr Molly while others made notes which also further signalled that the students were again engaged by this MMO as demonstrated in Figure 6.4 below.



Figure 6.4 Some students looking at Dr Molly while others were jotting down personal notes

MMOs resulting from a combination of lecturer explanations, gestures and/or actions *[LE+G/A]*

Table 6.2 above shows that lecturer explanations alongside gestures and/or actions were the sixth highest type of MMO out of the nine that manifested in Dr Molly's lectures, which had a total frequency of 13 out of 129 across the two lectures. This MMO type was characterised by occurrences where Dr Molly explained while performing a gesture and/or action. For instance, in episode 4 of lecture 1, during a whole class discussion about the processes of the cell cycle. Dr Molly explained to her students that "… *ideally mitosis is made up of four (showing four fingers) phases right, the last one which is telophase which can be subdivided into something early telophase and late telophase. When the cell undergoes late telophase then cytokinesis also starts. So, there is a little bit of an overlap and when telophase ends the cytokinesis continues until the whole cell divides into two identical cells."* While explaining the phases of mitosis Dr Molly gestured using her fingers to represent and place emphasis on the four phases of mitosis. This type of MMO resulted in student 1 being interested in knowing "*How do we separate the cytokinesis process from telophase?".* Student 1's question provided evidence that this explanation that was offered by Dr Molly stimulated some of the students' thinking which signalled that this MMO engaged the students, particularly those who prefer to learn auditorily and visually. Moreover, what was noteworthy about this incident was that, unlike previous instances where Dr Molly was the one asking the questions, this time it was the student who initiated the discussion by posing a question. Dolmans et al. (2016) further argue that when students ask questions, this results in deep impactful learning because they are actively reflecting on the presented content as well as formulating personal meanings. Therefore, this finding highlights the importance of lecturers encouraging students to actively ask questions during lectures.

MMOs resulting from a combination of lecturer explanation and visual representation [LE+VR]

The SE combination of lecturer explanation and visual representations the second lowest frequency in the two lectures as represented by Table 6.2 above. This type of MMO had a total frequency of 10 out of 129 across both lectures. Such MMOs manifested during incidents where Dr Molly provided an explanation while referring to a visual representation. An example of such an MMO resulted in episode 4 of lecture 1, where there was a whole class discussion about the processes of the cell cycle. During this episode, Dr Molly explained the different processes of the cell cycle to the students as shown in **extract B** below.

Extract B

1. *M: Now, let's look at the cell cycle as the entire process generally, or rather you can divide the two main components, but they lot more phases than just two components. As I said, we are not going to go into details of what happens in one of the components but really focus on the different phases of the other components the two components are interphase in mitosis which later we are going to expand to cytokinesis. So basically, the two main components those ones, the one that includes mitosis and cytokinesis as one component and the rest of the cell is interphase. Previously scientists thought that most of the activities of the cell happen during cell division, which is mitosis and cytokinesis, but later they discovered that over 90 % of the activity of the cell happens during interphase. So, there are a lot of things that happen during interphase, and it's also divided into its own phases but if I keep on saying we are not going to focus on that one. Just to give you an impression, one idea of what goes on during the cell cycle.*

While explaining, Dr Molly instructed her student to look at the image of the 2D cell cycle which was colourful and annotated. The 2D image clearly showed the different cellular processes that were happening at the different stages of the cell. Colourful images are known to attract students' attention (Thyberg et al.,2024), this was no exception in Dr Molly's case, as most students were seen looking at the image as represented by Figure 6.5 below, which evidenced that this MMO engaged the students.

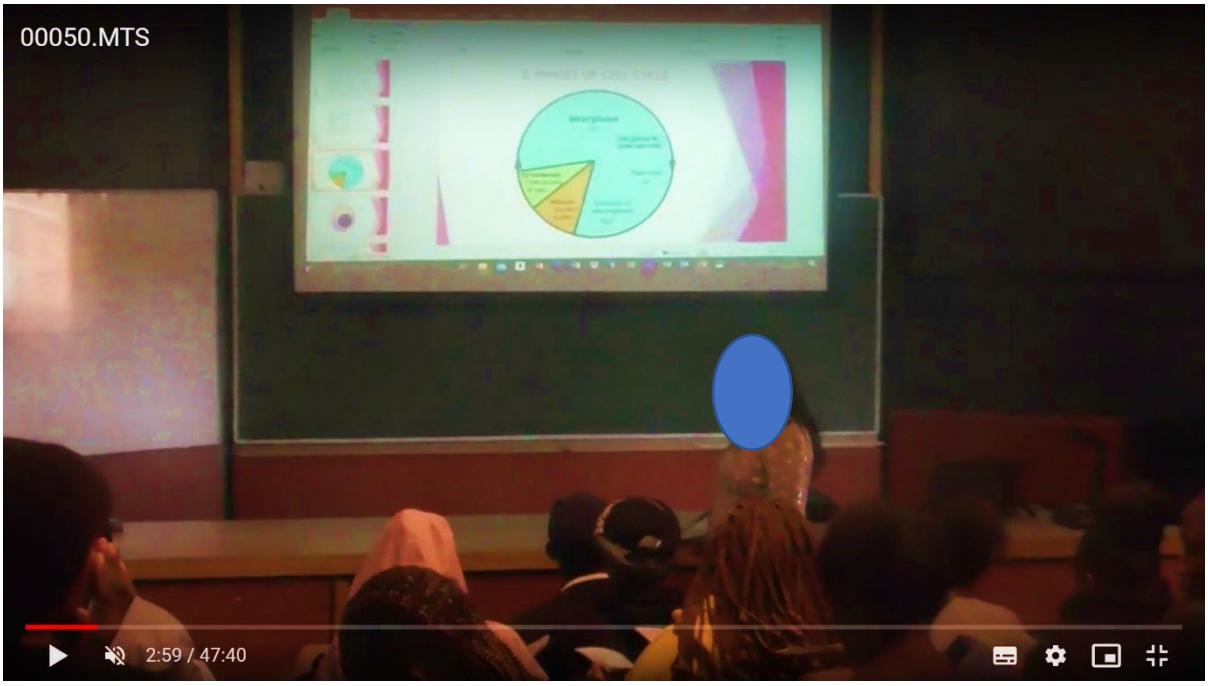


Figure 6.*5 2D colourful image of the cell cycle and how students engaged with the image*

This MMO highlights the importance of lecturers providing clear explanations supported by colourful images, especially when explaining complex biology processes as argued by Thyberg et al. (2024).

MMOs resulting from a combination of mnemonic and question [MNM+Q]

A mnemonic alongside a question SE combination had the lowest frequency of 2 out of 129. This means that in Dr Molly's lectures, there were fewer occurrences where such an MMO type manifested. Although that was the case, this was one out of three fascinating MMO types that were not documented in the previous case. A mnemonic is considered a memory T&L strategy that can help students remember and make meaning of large chunks of information (Agarwal, 2019). For example, in lecture 1 of episode 4, there was a whole class discussion about the phases of mitosis, which are part of the processes of the cell cycle. Dr Molly used two of the following mnemonics "...***P**lease **M**eet **A**t **T**enor and PMAT*. The first mnemonic was structured in a sentence form where each word represented each phase of mitosis in the order in which they follow each other (please **-prophase**, meet **-metaphase**, at **-anaphase** and ten-**telophase**). The second mnemonic **PMAT** was more of a brief acronym (forming a word-like) where again each letter represented each phase of mitosis in the order in which they follow each other (**P**rophase, **M**etaphase, **A**naphase and **T**elophase). While explaining the mnemonics Dr Molly asked the question "*...so the first one is?*" as shown in line 1 of **extract C** below. Given that this question required students to recall from their memory this supports the claim by Agbowuro et al. (2016)' that mnemonics usually promote surfaced learning and memorisation or cramming, and this is further evidenced by the subsequent series of questions and answers shown by line 2 to 5 of extract C below.

EXTRACT C

1.	*M: Remember please it's please meet at Tenor PMAT, right? so the first one is?*
2.	*Ss: Prophase!*
3.	*M: Now that prophase is divided two subphases which is early prophase and late prophase and then from there what is the next one?*
4.	*Ss: Metaphase!*
5.	*M: Metaphase is the second one and the third one?*
6.	*Ss: Anaphase!*
7.	*M: Anaphase, the fourth one?*
8.	*Ss: Telophase!*

Even although that was the case, lines 2,4,6 and 8 of **extract C** above show that the MMO resulting from the use of mnemonics engaged students, as they were able to mention all the phases of mitosis as they consecutively follow each other. This sentiment was also expressed by Dr Molly during the VSRI when asked why she used mnemonics, and she said:

"*So, that was used to assist students to know what is there or the stages and how they follow each other. That mnemonic was not really meant to make them understand it was meant to help them know what is there and the sequence, how they follow each other…Then they can make that connection from what is happening in one phase to the next. If they do not know the arrangement of those phases, the organisation of those phases and you simply tell them what is happening in each phase. They won't be able to make that link, they won't be able to see the continuous development of activities in the different phases. They won't be able to connect it, they won't be able to connect all the different phases and that's one big problem with our students. They are taught what is happening in Anaphase, what is happening in Telophase, they are taught what is happening in the metaphase, but they cannot link. They cannot see the transition from one phase to the next, they simply memorise what is happening in one phase. So, for me, I think if they can understand the sequence of the phases and the names of the phases, and then you explain what is happening in each phase, and then you move to the next one, then they will be able to see the continuity. The transition from one phase to another and the continuity of the whole cycle.*"

Although mnemonics are known to promote rote learning or cramming, which could explain why they were the least manifesting MMO type in Dr Molly's lectures. Dr Molly's response reveals that she did not use the mnemonic merely for memory purposes but intentionally used them to enable her students to see the links that exist between the different phases of mitosis.

6.2.2. Level 2 MMOs that resulted from the combination of three types of SEs

Table 6.2 above reveals that there was a total of three out of fourteen SE combinations that manifested in Dr Molly's two lectures which involved:

1. A gesture and/or action alongside visual representation and lecture explanation [GA+VR+LE]
2. A question alongside gesture and/or action and visual representation [Q+G/A+VR]
3. A lecture explanation alongside analogies and questions [LE+ANLG+Q]

The three MMO types emanated from the simultaneous use of three different SEs and had a total frequency of 36 out of 170 in both lectures. The MMO types that manifested in this level were more complex than those observed at level 1. In the sub-sections below, I further explained and provided more incidences of how these MMO types manifested in Dr Molly's two lectures.

MMOs resulting from gestures, visual representations, and lecturer explanation [GA+VR+LE]

Table 5.2 above reveals that gestures alongside visual representations and lecturer explanation were the highest used SE combination by Dr Molly, with a frequency of 17 out of 36. Such an MMO type occurred in episode 1 of lecture 2, where Dr Molly was engaged in an open class discussion with the students. During the discussion, Dr Molly and the students were trying to clear the confusion between telophase and cytokinesis. During this instance, Dr Molly began by explaining to the students "*The cell will start by undergoing early telophase. During late telophase then cytokinesis will also happen, and its main responsibility and function is to separate the cytoplasm into two identical daughter cells. We are going to look at this for now.*" While explaining Dr Molly pointed at the projected 2D colourful, animated and labelled image showing telophase as shown in Figure 6.6 below.

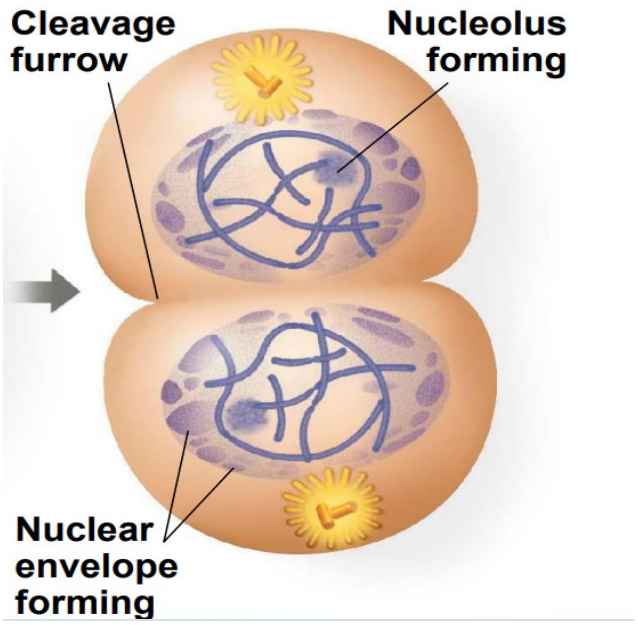


Figure 6.6 2D colourful image showing telophase

Dr Molly mentioned that she also prepared a video but unfortunately "*...my video is not working here…This video was supposed to demonstrate what happens during cytokinesis, but let's look at what is happening over there.*" Even though the video did not work because of the technological glitches, Dr Molly still managed to improvise and use the animated 2D image to focus the students on the central concepts that were aimed at helping them see the difference between telophase and cytokinesis. In the video, most students were seen looking at the projected animated image while some wrote down notes, this was interpreted to mean that the students were engaging with the manifesting MMO during this episode. What this incident further suggested is that technological challenges or glitches can sometimes hinder the type of MMO from manifesting during lectures. This occurrence shows that when planning a lecture, particularly when thinking about how best to help students to better understand the difference between telophase and cytokinesis, Dr Molly might have realised that she needed to use more than just explanations and static visuals as she did in the previous lecture. She incorporated the animated images that demonstrate to the students the key events that happen in the two phases to clarify their confusion, as these types of visual representations are more interactive and memorable (Nocek, 2021). These results highlight the importance of lecturer awareness of students' sources of confusion for better planning which could result in the manifestation of targeted MMOs.

MMOs resulting from questions, gestures and/or actions and visual representations [Q+G/A+VR]

Table 6.2 above indicates that questions, gestures and/or actions and visual representations were the second-highest SE combinations that were used by Dr Molly to promote the manifestation of these types of MMOs, which had a total frequency of 13 out of 36. An example of such an MMO type manifested in episode 4 of lecture 2 where Dr Molly and the students were discussing the structure and function of epithelial tissues. During the incident, Dr Molly began by asking the students a rhetorical question (did not require a response) by saying "*Remember cells make up tissues, isn't it!*?!". This question was aimed at refreshing the students' memories about what tissues are as they had already discussed this aspect in the first episode of this lecture. While asking the question, Dr Molly did not wait for students to respond and went on to further explain that "*The epithelial tissue is also made up of cells. So, there are three different types these are cuboidal, columnar, and squamous"* while she pointed at the slide containing notes as represented by Figure 6.7 below.

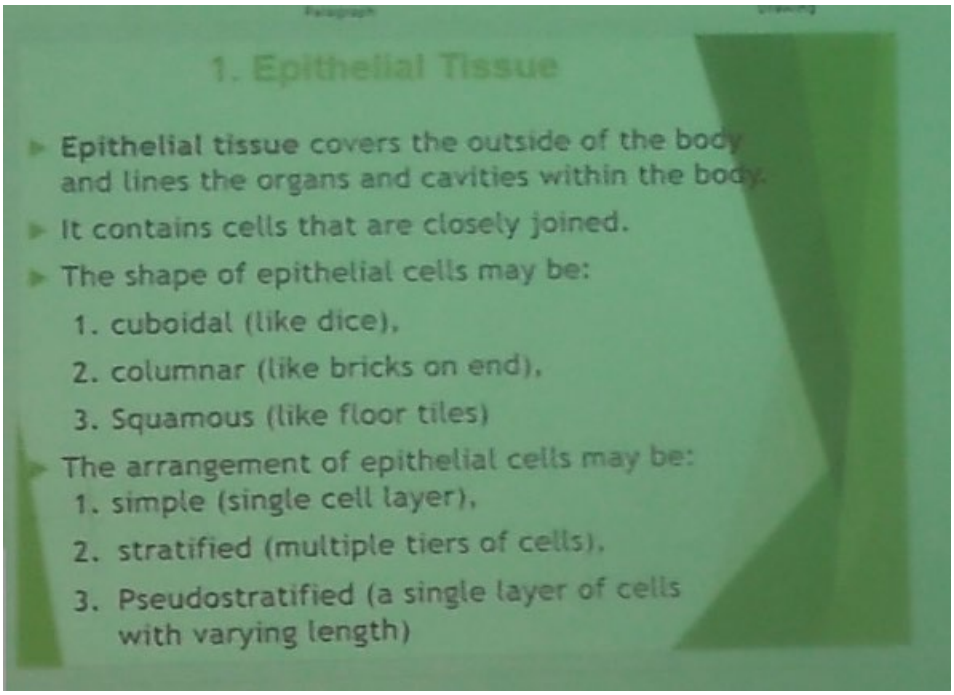


Figure 6.7 slide containing notes about the epithelial tissue

Dr Molly explained using concise and well-organised bullet points which contained key elements in the slide in Figure 6.7 above. These are aspects of an 'effectively' designed slide as suggested by Baker et al. (2018). During the explanation, a student was heard saying that Dr Molly was "*...biting your tongue*" which meant that they did not understand what she had just explained. This murmur still showed that this manifesting MMO engaged them even though they were having difficulties accessing and/or organising the presented information. The possible reason for this incident could be because Dr Molly's slide was mainly text although it served as a visual, it still did not help the students see the shape and arrangement of the epithelial cells that she was referring to, especially given their abstract nature. When looking closely at this terminology used to describe the shape and arrangement of the epithelial cells it was somewhat complex which could have also been another source of difficulty that prevented the students from understanding Dr Molly's explanation. That is why Nocek (2021) says that 'vibrant' visual representations play a critical role in assisting students to cope with complex terminology and be able to establish the relationships that exist between structure and function during meaningful learning. This incident demonstrates a need for lecturers to provide comprehensive explanations that are supported by visual representations aimed at providing access to complex content during MMOs.

MMOs resulting from a combination of lecturer explanation, analogies, and questions [LE+ANLG+Q]

Table 6.3 above shows that lecturer explanations alongside analogies and questions [LE+ANLG+Q] was one of the lowest-used SE combinations, with a frequency of 6 in the two lectures. This MMO type was characterised by events where Dr Molly explained while using an analogy and asking a question simultaneously. Episode 2 of lecture 1 was an example of where such an MMO type manifested. Here, Dr Molly was still trying to convince her students about the difference between chromosomes and chromatids after she had attempted numerous times as shown by extract D below.

Extract D

1.	*M: Okay now let's start we have a chromosome made up of a protein on the DNA wrapped around it now the cell needs to divide. This chromosome has to replicate, and their replication produces two identical pieces of genetic material right now how do we call these two pieces of genetic material that have to come from the chromosome that has replicated called the sister chromatids right, so which came from one chromosome which has replicated into two similar structures which are called chromosomes made up of two halves or two identical halves. Then let's move from there let's suppose you now separate the two halves you've cut me into halves okay, that one half is not a human being the other half alone is not a human being, but the two halves put together from a human being. A human being, in this case, represents a chromosome, the half, in this case, represents a chromatid. Now let's suppose it's possible to separate my halves and this one half grows completely into a human being with two hands and two legs and whatnot, and the other one grows completely into a full human being, I then have a half that has developed into the other side, right?*
2.	*Ss: Yes!*
3.	*M: That half is now being called a human being and the other half is called a human being. The halves have separated in each one each growing into a human being, the same applies to chromatids after duplication cutting into two identical parts.*
4.	*(Ss started to clap hands)*

Line 1 shows that Dr Molly began by providing her students with a scientific explanation of the composition of the chromosome and why it needs to undergo the process of replication to form two identical sister chromatids. She re-explained the replication process of a chromosome to form two sister chromatids by using an analogy of herself (a human being) being cut into two halves. This was regarded as an analogy because Dr Molly described the replication process of chromosomes to form sister chromatids using familiar concepts of a human being cut into two halves. This meant that she used the

concept of a human being to symbolise a chromosome, and the two halves of the human being used to symbolise the sister chromatids.

In line 1, to further emphasise the difference between a chromosome and a chromatid, Dr Molly said to her students that the two halves are not necessarily human beings, alluding that the two sister chromatids are not necessarily chromosomes. To assess whether the students followed the analogy, Dr Molly asked a closed-ended question that required students to either agree or disagree whether they thought chromatids had developed into a chromosome. The students responded in unison saying "Yes". The students' response indicates that they understood the analogy and now perhaps see the difference between chromosomes and chromatids. In the video, the students were seen clapping their hands also revealed in line 4. The students' clapping of hands was interpreted to mean that this analogy was effective in clarifying the confusion and helping them see the difference between chromosomes and chromatids. This signalled that the manifestation of this MMO engaged the students, although the choice of analogy used by Dr Molly was not scientifically accurate as humans do not replicate to make identical copies of themselves. Dr Molly spent a lot of time trying to explain and clarify this misconception/misunderstanding/confusion. This became an area of interest during the VSRI, and I asked Dr Molly why she felt it was her duty to ensure that her students understood the content she was teaching rather than just prioritising teaching the animal tissue content that she had prepared for lecture 2. Dr Molly explained:

"*So, I did come into academics because of my qualifications or because of research or the way some people become a lecturer. I was trained as a high school teacher. So, from that training, I got to understand that before you move ahead before you continue with whatever it is that you want to teach. You have to have a solid foundation in the sense that the students or learners understand the basics first before we can proceed. If are you just going to ignore the things that they do not know, then the subsequent lectures will not be effective. They won't be able to understand because they need that, that basic, foundational understanding for them to understand the subsiding part. So, when I realised that they didn't understand cytokinesis and chromosomes. I had to go back because to me that is basic, I had to go back and be sure that they understood that because everything else that they are going to learn later was based on the understanding of those things. So, I'd rather spend time making them understand than rushing to new concepts...*"

Again, Dr Molly's response reveals that her students' understanding of content was central to her practice, which further supports that Dr Molly's meaning making practices are influenced by the constructivist perspective which she mentioned as one of her teaching philosophies. She sees the content that she is teaching as being interconnected in nature and not necessarily existing in isolation, thus signifying that her teaching approach is cumulative in nature (Reining et al. 2022). Although there is evident that this manifesting MMO engaged the students as it moved them from the unknown to the

known, but there is a serious need for teacher educators to use scientifically informed examples and/or analogies to avoid perpetuating new misconceptions.

6.3.3. Level 3 MMOs that result from the combination of four types of SEs

Table 6.2 above reveals that there were two SE combinations that led to the manifestation of MMOs in Dr Molly's lectures. The manifesting MMOs had a total of 10 out of 170 and were documented as:

1. A lecture explanation alongside a gesture and/or action, visual representation, and question [LE+ G/A+VR+[Q]
2. Feedback alongside a lecture explanation, gesture and/or action and visual representation **[** FDBK + LE+ G/A + VR]

The SE combinations at this level had the lowest frequency as compared to the other two levels of MMOs types. These results reveal that there were a few complex MMOs that manifested in Dr Molly's lectures which had the potential to accommodate **students with three or four learning preferences**. In the sub-sections below, I further elaborate on each MMO type and provide incidences of how they manifested in Dr Molly's two lectures.

MMOs resulting from a combination of lecturer explanation, gesture and/or action, visual representation, and question [LE+ G/A+VR+Q]

Table 6.2 above shows that lecturer explanation, gesture and/or action, visual representation and question were the highest used SE combinations at this level with a total frequency of 6 out of 10. Such MMO types involved Dr Molly explaining concepts with gestures, visual representations and questions. For instance, in episode 4 of lecture 1, during a whole class discussion about the processes of the cell cycle. Dr Molly began by pointing at the 2D animated and labelled image showing telophase shown in Figure 6.6 above. Dr Molly simultaneously explained to the students that they should "…*notice that the first cell is in telophase and now contains two nuclei when in the previous stages it only had one nucleus...*" Dr Molly then asked the close-ended question "*where did the two nuclei come from?*". Unfortunately, the students were not able to answer this question, but they were heard murmuring in the video which showed that they were engaged by this type of MMO although they might not have been sure of their responses. As in the previous incident, Dr Molly did not render this as a lost MMO but rather asked the question again leading to the manifestation of another MMO, thus showing that she wanted to ensure that her students continued to critically think and engage with it. Dr Molly then pointed at the 2D animated and labelled image showing telophase again and asked the students to look at the image and this time she paused for a while before proceeding. The 'pause' was interpreted to mean that Dr Molly wanted all the students to engage with the projected image and in the video and it can be confirmed that most of the students engaged with it. Dr Molly then proceeded to explain that the 2D image projected depicting telophase and asked the students to think about where the two nuclei came

from or what formed the two nuclei. The students responded by saying that "*mitosis*" formed the two nuclei. This incident confirms Fraser's (2018) assertion that rephrasing and giving students ample time to think about the question supports critical thinking predominantly in higher learning contexts. This reveals that lecturers need to continuously rephrase their questions or alter their questioning styles and provide enough time to foster MMOs that will promote critical thinking among their students.

MMOs resulting from a combination of feedback alongside a lecture explanation, gesture and/or action and visual representation [FDBK + LE+ G/A + VR]

Feedback alongside lecture explanation, gesture and/or action and visual representation had the lowest frequency of 4 out of 10 as tabulated in 6.2 above. This means that Dr Molly used this SE combination the least in her lectures. This type of MMO involved Dr Molly building on students' ideas in the form of feedback and explanation while referring to a visual representation. For example, such an MMO type manifested again in episode 2 of lecture 1, where there was a whole class discussion based on defining the cell cycle. During this discussion, Dr Molly began by asking the students how many pairs of chromosomes humans have and one of the students indicated that there are 23 pairs. Dr Molly provided the student with feedback by saying "*Right, we have 23 pairs"***.** Dr Molly re-voiced the students' response which Mapplebeck and Dunlop (2021) believe is done to affirm the student's response and promote collaborative learning where students are continuously engaging with each other's responses. Dr Molly continued to explain to the students that *"The first 22 pairs of chromosomes are called autosomes and the last 23rd pair is known as the sex chromosomes because they decide if a baby will be born male or female…So, let's ignore all the other chromosomes and let's pick this one and try to follow it and see what happens during cell division."* Whilst explaining, Dr Molly pointed at the 2D labelled and colourful image showing a chromosome which most of the students were seen to be engaging in the video, Dr Molly then asked the students "*are you following*?' (a close-ended question) and they provided a chorus response of "*yes"* which indicated that they were. Therefore, it can be said that this type of MMO engaged the students, particularly because the explanations was supported by a visual which was effectively used to focus the students on the key aspects of the content presented.

6.3. Discussion of the analysis and Conclusion(s)

In this chapter I presented an analysis of data from Dr Molly, the second case. The analysis identified fourteen distinct types of MMOs, which emerged from combinations of three out of four social exchanges (SEs): talk, visual representations, as well as gestures and/or actions. These MMOs were categorised into three levels of complexity, as outlined in Chapter 4. Most MMOs in Dr Molly's lectures manifested **at Level 1 and primarily engaged students who preferred auditory learning**. These MMOs frequently relied on lecturer explanations and both open and closed-ended questions, thus engaging students in recalling, reasoning or justifying their point of views and listening for information during lectures.

Dr Molly's use of mnemonics and analogies led to the manifestation of MMOs at this level that appeared to engage students as they were able to conceptualise abstract concepts (chromatids and chromosomes). Mnemonics, for example, were particularly effective in the manifestation of MMOs that helped students sequence the phases of mitosis, while analogies were instrumental in clarifying distinctions between chromosomes and chromatids. Therefore, revealing that the use of mnemonics and analogies could be seen as a powerful teaching strategy that can lead to the manifestation of MMOs that not only enhance students' grasp of abstract scientific concepts but also promotes engagement and knowledge retention. While that is the case, it is important for biology lectures to use scientifically correct analogies to avoid creating new misconceptions during manifesting MMOs in their lectures.

Dr Molly's use of open and closed ended questions appeared to foster the manifestation of MMOs that promoted not only engagement among students but also enabled dialogic interactions between her and the students. What appeared to strengthen such MMOs that involved questions was that she often paused to wait for students to respond and rephrased questions to ensure clarity and accessibility, thus, creating opportunities for more thoughtful engagement amongst students. The findings suggests that thoughtful and varied questioning, combined with 'wait time' and clarity, are all crucial in the manifestation of MMOs. Also, Dr Molly's willingness to revisit misunderstood concepts using questions, coupled with her constructivist philosophy of building on prior knowledge, emphasise the importance of a student-centered teaching style in the manifestation of MMOs.

Level 2 MMOs, which were moderate in complexity, accounted for the second-highest proportion of the manifesting MMOs in Dr Molly's lectures. These MMOs at this level often involved a combination of gestures, visual representations, and explanations, providing a more interactive learning experience. MMOs that manifested from the use of animated 2D visual representation seemed to play a significant role in engaging students who preferred visual learning and again helped clarify abstract biological processes. These MMOs also demonstrated Dr Molly's ability to adapt her teaching to align to her students' **different learning preferences** and needs, thus emphasising the importance of a lecturer having knowledge of their students.

Level 3 MMO types which were considered the most complex, were the least frequent but particularly effective in engaging students with diverse **learning preferences.** These MMOs mainly integrated feedback, open and close-ended questions, gestures and/or questions, and visual representations during her lectures. While these MMOs often engaged students in various ways such as note-taking, listening, asking questions and answering questions, several challenges hindered their manifestation in Dr Molly's lectures. Technical glitches disrupted the use of visual representations, forcing Dr Molly to improvise with gestures and/or actions as well as verbal explanations. While she demonstrated resourcefulness in overcoming these obstacles, such disruptions show the importance of reliable

technological support in fostering effective MMOs, as well as the importance of a lecturer having thorough knowledge of the content that they are lecturing. Also, the restrictive layout of the lecture venue further limited her mobility, reducing her ability to interact with students seated at the back and occasionally leading to disengagement and missed MMOs. These results suggest that it important for a biology lecturers to have knowledge of their lecturing context and their students as these factors can impede on the manifestation of MMOs and student engagement. Additionally, the brevity of her lectures, caused by campus disruptions, constrained the depth and variety of complex MMOs (appearing at levels 2 and 3), thus revealing that time constraints can again affect the manifestation of MMOs.

Even so, the analysis again highlighted Dr Molly's use of humour as an effective tool for creating a positive and inclusive classroom atmosphere, where students freely engaged with the manifesting MMOs in her lectures. These results could be explained by the fact that humour reduces student anxiety and fosters a learning environment where students felt comfortable engaging with the material. This was particularly beneficial when addressing challenging or abstract topics, as it helped students overcome their fearfulness or doubts and actively participate in discussions. Thus, emphasising that lecturer's personality and the role of a constructivism as a teaching philosophy may influence the manifestation of MMOs and students' engagement in biology lectures.

In summary, this chapter has provided valuable insights into the importance of biology lecturers integrating diverse SEs, planning and tailoring teaching approaches to foster dialogic interactions, and making use of other SEs like mnemonics and analogies to simplify complex biology content. While challenges such as contextual factors such as time constraints, technological issues, and classroom limitations occasionally hindered the manifestation of MMOs, Dr Molly's constructivist philosophy, knowledge of the content, use of humour, and adaptability enabled her to create an engaging and inclusive learning environment. These findings highlight practical implications for designing biology lectures that promote critical thinking, **accommodate diverse learning preferences**, and prepare students for their future roles as educators.

In the next chapter, the analysis will turn to Dr Moses lectures, exploring the manifestation of MMOs in her lecturing of osmoregulation and excretion to third-year biology students**.**

Chapter 7

Case 3 Dr Moses'

Topics: Excretion and osmoregulation

Class: 3rd year biology students

7.0. Introduction

The previous chapter introduced the second case that was presented by Dr Molly who taught mitosis and animal tissues to 3rd year students. This chapter presents Dr Moses's background information and lecture overview and presents the findings from the analysis of his lectures using the same data analysis processes detailed in Chapters 3 and 4. To conclude the chapter, I provide insights that aim to answer the research questions of this study.

7.1. Dr Moses's background information and lecture overview

Table 7.1 below is a summary of Dr Moses's background information and an overview of the observation of his two lectures as a means of framing the results of this study. The information presented in Table 7.1 is further expanded upon in the subsequent sub-sections below.

Table 7.1. Dr Moses's summarised background and lecture information

Age/Race/Experience	Qualification/s held	Teaching Philosophy	Class taught	Duration of the lectures/minute		Number of PSTs taught	Content taught
				Lecture 1	Lecture 2		
African male. About 50 years old. Teaching experience 25 years	B.Ed., BSc Hons, MSc Ed, D.Ed.	PCK	3rd-year PSTs	90	45	64	Osmoregulation and excretion

7.1.1 Content overview of the topics of osmoregulation and excretion and challenges associated with teaching the topics

Dr Moses was teaching the topics osmoregulation in lecture 1 and excretion in lecture 2. The process of osmoregulation, as explained by Shaw (2012), is essential for maintaining the balance of water and salts across cell membranes in living organisms. This process regulates osmotic pressure, influenced by the movement of water, electrolytes (like sodium and potassium, which dissociate into ions), and non-electrolytes (which do not dissociate) (Shaw, 2012). In mammals, three key fluids are involved, namely blood plasma, interstitial fluid, and intracellular fluid, all of which require proper osmotic regulation to maintain functionality. The kidneys play a pivotal role in balancing water and electrolytes and/or salts by excreting or conserving them, depending on the body's needs, for example, during dehydration.

According to Reece at al. (2018) osmoregulation is the regulation of water and electrolyte balance to maintain cellular and systemic stability in different organisms found in different environments as explained below:

- **Marine Animals**: Saltwater fish counteract water loss by drinking seawater and excreting excess salts through specialised gill cells and kidneys.
- **Freshwater Animals**: These organisms avoid water overload by excreting large volumes of dilute urine while actively absorbing salts through their gills.
- **Terrestrial Animals**: Adaptations such as keratinised skin and specialised excretory mechanisms help minimise water loss in dry environments. Some, like the kangaroo rat, rely on metabolic water to survive without direct water intake.

Djamahar et al. (2020) describes the role of excretion in osmoregulation as the removal of toxic wastes from the body. Similarly, Reece et al. (2018) says that excretion involves the removal of metabolic waste products, such as urea, carbon dioxide, and ammonia, generated from cellular processes. The urinary system, lungs, and skin are all involved in the excretory processes, ensuring waste is expelled through urine, exhaled carbon dioxide, and sweat. According to Djamahar et al. (2020), in humans, the kidneys play a pivotal role, with each nephron functioning as the structural and functional unit. The key processes in excretion stated by Shaw (2012) include:

- **Ultrafiltration**: Blood is filtered in the glomerulus, producing a filtrate containing water, salts, glucose, amino acids, and urea.
- **Selective Reabsorption**: Useful substances like glucose and ions are reabsorbed into the blood from the nephron.
- **Secretion**: Active transport removes additional wastes like hydrogen ions and toxins into the nephron for elimination in urine.

In other animals, waste excretion varies (Reece et al., 2018; Shaw, 2012). For example, insects use Malpighian tubules to conserve water and excrete uric acid. While, birds and reptiles excrete uric acid, minimising water loss by producing a paste-like excretory product. A failure in osmoregulation and excretion can lead to the accumulation of toxins which can contribute to the disruption of cellular functions, and result in conditions like high blood pressure due to changes in blood plasma volume (Reece et al., 2018).

Despite the importance of these processes in living organisms, the teaching and learning of osmoregulation and excretion presents challenges like many other biology topics. According to Rıstanto et al. (2021), one of the challenges is caused by traditional passive instructional methods that most biology teachers use, which often reduce students to mere note-takers or passive listeners, limiting their

engagement with the complex biological processes. This approach leads students to memorising the content without fully understanding the concepts and seeing its importance in their daily lives. To overcome this, Rıstanto et al. (2021) and Djamahar et al. (2020) recommend that biology lecturers and teachers alike consider using constructivist approaches in their classrooms. Specifically, Rıstanto et al. (2021) highlight the benefits of using Cooperative Integrated Reading and Composition (CIRC) models based on a scientific approach to foster conceptual understanding of excretion and osmoregulation. The CIRC is a collaborative learning strategy where students work together in small, diverse groups to read, discuss, and write about presented excretion and osmoregulation problems (Rıstanto et al., 2021). It integrates reading comprehension with writing activities to reinforce understanding of the content. Thus, according to the Rıstanto et al. (2021), the CIRC model has the potential of promoting active learning, critical thinking, and effective communication, helping students understand the two processes and apply their knowledge in real-life situations.

7.1.2. Context of the lecture, resources, and technologies used by Dr Moses

Dr Moses lectured a manageable group of 64 third-year students in his lecture venues. These 3rd years had completed two full years of natural science lectures and were now biology majors. Dr Moses's lecture venue was a theatre with one screen at the front of the lecture venue. The students in the venue were seated next to each other in ascending and closely spaced parallel rows, thus the lecturer was positioned in the front of the venue. Dr Moses also used prepared PowerPoint slides as the main tool for presenting information as well as the school's LMS called Sakai for uploading all his content like in the two previous cases.

7.2. Presenting the findings

Table 7.2 below, summarises the MMO types observed in Dr Moses' lectures. A total of fourteen MMO types were identified in the two different lectures. Among these, seven MMO types were observed at level 1. The occurrence of these seven MMO types amounted to 63 out of 108 instances, constituting nearly 60% of the total across all three levels. This indicates a significant presence of MMO types that occurred at level 1 in Dr Moses' lectures, primarily targeting students with one **or two learning preferences.** In contrast, five MMO types were categorised at level 2, representing 36 out of 108 instances (one in three) across the three levels. This suggests a lower fraction of MMO types manifesting in Dr Moses' lectures that catered for students with **two or three learning preferences.** Only three out of the fourteen MMO types were observed at level 3, accounting for less than 10%. These findings indicate an even smaller proportion of MMO types that accommodated students with three or more **learning preferences.**

Table 7.2 Summarised findings of the types of SEs and MMOs that manifested in Dr Moses's lectures in comparison to the previous cases.

Level of MMOs	Description of each level	Types of MMOs manifesting across the two lectures	Frequency of type of MMO across lectures	Manifesting forms of engagement across the two lectures
1	**Combination of two types of SEs**	1.[LE+WRTN]	**13**	**-Some students are looking at the screen** -A few students have **their hands raised** and a few are asking questions **-A few students are making notes** **-Some students are listening to the lecturer, and most are disengaged-looking at their phones** **- Some students are seen laughing**
		2.[VR+Q]	**11**	
		3[FDBK+WRTN]	**10**	
		4.[WRTN+Q]	**9**	
		5.[LE+Q]	**8**	
		6.[G/A+Q]	**8**	
		7.[LE+G/A]	**4**	
		Proportion of the total MMOs	**63**	
		Proportion of the total in (%)	**58**	
2	**Combination of three types of SEs**	1.[GA+VR+LE]	**10**	**-Some students are looking at the screen** -A few students have **their hands raised** and a few are asking questions **-A few students** are **making notes** **-Some students** are **listening** to the lecturer, and most are **disengaged-looking at their phones** **- Some students** are seen **laughing** **- All Students** are seen **making drawings and discussing with their peers** **-All students** are seen **writing labels**
		2.[Q+G/A+VR]	**8**	
		3. FDBK+LE+WRTN]	**8**	
		4.[LE+ WRTN+ Q]	**7**	
		5. FDBK+ G/A+VR]	**3**	
		Proportion of the total of MMOs	**36**	
		Proportion of the total in (%)	**33**	
3	**Combination of four types of SEs**	1.[LE+WRTN+G/A+VR]	**6**	**- Some students** are **looking at the screen** **-A few students** have **their hands raised** and a **few are asking questions** **-A few students** are **making notes** **-Some students** are **listening** to the lecturer, and **most are disengaged-looking at their phones** **- Some students** are seen **laughing** **- All Students** are seen **making drawings** and **discussing with their peers** **-All students** are seen **writing labels**
		3. FDBK] +Q+G/A+VR]	**3**	
		Proportion of the total of MMOs	**9**	
		Proportion of the total in (%)	**8**	

7.2.1. Level 1 MMOs that resulted from the combination of two types of SEs

The information presented in Table 7.3 highlights that a total of fourteen different MMO types were observed in the two lectures. From these fourteen SE combinations, seven MMO types were identified with a combined frequency of 63 out of 108 instances (two in three) at this level. The seven MMOs consisted of the following:

1. Lecturer explanation and writing and/or drawing [LE+WRTN]
2. A visual representation and a question [VR+Q]
3. Feedback and writing and/or drawing [FDBK+WRTN]
4. Writing and/or drawing and questions WRTN+Q]
5. A lecturer explanation and a question [LE+Q]
6. A gesture and/or action and a question G/A+Q
7. A lecturer's explanation and gestures and/or actions [LE+G/A]

In the subsequent sections, I elaborate in greater detail and provide examples of how these seven MMO types that were identified at level 1 manifested.

MMOs resulting from a combination of a lecturer explanation and writing and/or drawing [LE+WRTN]

As can be seen in Table 7.2 above, lecturer explanations alongside writing and/or drawing were the most frequently observed MMO types, occurring 13 times out of 63 instances at this level. This finding highlighted the prevalent use of lecturer explanation supported with writing and/or drawing to emphasise crucial aspects of the content. For instance, during episode 3 of lecture 1, a whole class discussion on osmoregulation took place, where Dr Moses introduced various terminologies used to describe osmotic states namely: isotonic, hyperosmotic and hypoosmotic**.** During his explanation, Dr Moses wrote and underlined the key terminology on the whiteboard. During the episode, he said "…*So, when we compare the state or the conditions inside in terms of the solutes and the amount of water compared to what is happening outside, we use different terms. Now in the case where we have these two (Circles and underlined the word **water** and **solutes**) more inside, we normally use a term called Hyper (writing the word on the whiteboard).* According to Armour et al (2016) writing allows the facilitation of student notetaking, greater alertness, and attention among students. This was no exception in Dr Moses' case because as he was explaining and writing keywords on the board, most of the students were taking notes and some looking at the board, which evidenced that the manifesting MMO engaged the students during the lecture.

After the explanation, Dr Moses asked the students "…*because we are talking about Osmoregulation, will it be Hyper or Hypo?"*. The students did not respond to the close-ended question which may suggest that they did not know the answer and probably that they did not even understand the explanation provided by the lecturer. This finding could have emanated from the lack of clarity in Dr Moses' explanation of the concept of hyperosmolarity especially regarding the meaning of '*more inside*' whether it referred to water, solutes, or both. This is despite Dr Moses having three prepared slides at his disposal, which could have been utilised to explain again this concept more effectively. For instance, slide 1 (refer to Figure 7.1) clearly explained the hyperosmotic state as "*Animals that have a higher solute concentration than the environment are hypertonic."* Additionally, Figure 7.2 below also visually represented the solute concentration in a hyperosmotic state.

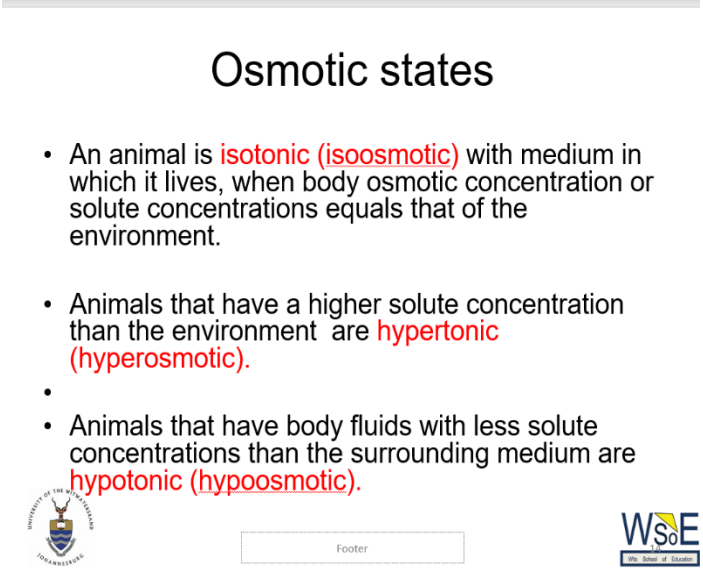


Figure 7.1 Slide showing the definitions of the different osmotic states.

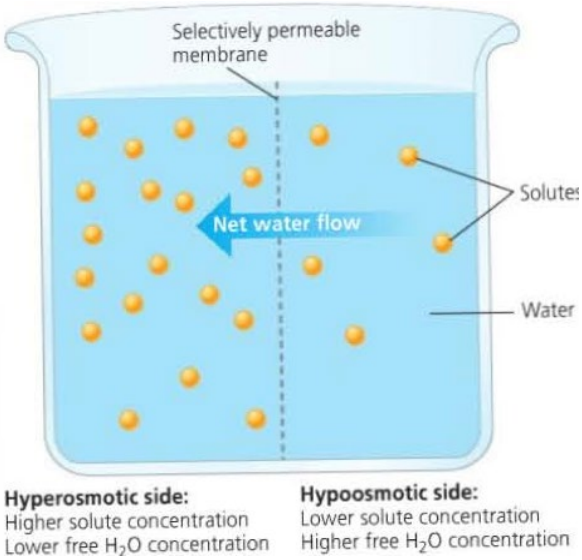


Figure 7.2 visual representation of the concentration of solutes in different osmotic environments

According to Newman (2020), lecturer explanations are crucial in enabling students to understand biological concepts, therefore they are an important tool that can be used to foster MMOs. However, the occurrence above shows that when lecturer explanations are not clear enough even when used alongside writing and/or drawing they can still impede students' understanding in terms of their ability to apply the content to new learning situations as well as their overall participation. Fischer (2013) further argues that explanations are fundamental strategies that teachers use to translate scientific jargon into relatable comprehensible information. Therefore, it is important that when lecturers explain, they pay attention to how they unpack the biological concepts while supporting with visuals. This means that they should explain clearly and using simple language that is familiar to the students from diverse

linguistic backgrounds as suggested by Newman (2020) to promote the successful manifestation of MMOs.

MMOs resulting from a combination of A visual representation and a question [VR+Q]

A visual representation alongside questions had the second highest frequency of 11 out of 63 at this level, which means that this was one of the most commonly occurring MMO types that manifested in Dr Moses' practice at this level. This SE combination involved Dr Moses posing questions based on a projected visual aid. An instance of this MMO type was observed in episode 8 of lecture 2, where a whole class discussion on nitrogenous wastes took place. During this episode, Dr Moses initiated the discussion by displaying a visual representation shown in Figure 7.3, which depicted various organisms and their respective nitrogenous waste products in the form of a flow diagram. According to Allen and Tanner (2017), flow chart diagrams or representations serve as powerful tools for logically demonstrating conceptual relationships.

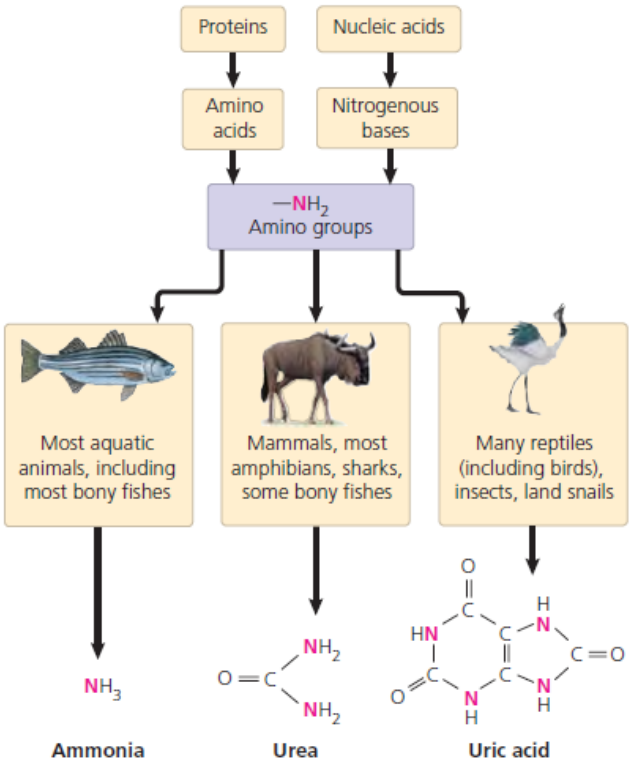


Figure 7.3 visual representation used by Dr Moses to teach nitrogenous wastes excreted by different organisms.

Dr Moses posed a question to the students regarding the type of waste produced by fish, while displaying an accompanying visual representation. Specifically, he asked, *"Looking at that picture, what form of waste does fish produce? Is that urea, uric acid, or ammonia?"* Dr Moses not only presented the image but also encouraged the students to actively interact with it to deduce or decode the form of waste produced by the fish. According to Allen and Tanner (2017), this questioning technique used by Dr Moses is referred to as a closed-ended question because it requires students to provide a one-word answer for which there was only one correct response. At this point, some students examined

the projected image, while some had already raised their hands to respond (signalling engagement). The students replied in unison saying, "*Ammonia*" providing further evidence of their engagement during this MMO. This finding validates the argument put forth by Cromley et al. (2013) that effective instruction from teachers plays a crucial role in enhancing students' engagement with visual representations. On the contrary, this finding also supports Allen and Tanner's (2017) claim that while this type of question aids in developing a fundamental understanding of concepts, it may also foster surface learning. Therefore, this result shows that whilst questions are important in engaging students and for creating MMOs, it is vital that lecturers vary their questions or further ask students to justify their responses to foster critical thinking.

MMOs resulting from a combination of feedback and writing and/or drawing [FDBK+WRTN]

The SE combination of feedback and writing had the third highest frequency of 10 out of 63 at this level. This means that this MMO type was one of the most frequently manifesting MMO types in Dr Moses' lectures. An illustrative example of this interaction took place in episode 4 of lecture 1 during a whole class discussion on various body fluids. During this episode, before providing feedback, Dr Moses began by asking the students a question "*Which substance is excreted by the lungs there?"* This was another closed-ended question that required a one-word response from the students hence they responded in unison, saying, "*Carbon dioxide*." This question led to the manifestation of an MMO which engaged the students, but it did not contribute much to developing what Vargas-Hernández et al. (2023) refer to as 'deep learning' which involves students elaborating further on their ideas to develop or strengthen critical thinking.

Dr Moses reiterated their response by affirming, "*So, it is carbon dioxide*," while simultaneously writing the chemical formula for carbon dioxide (CO_2) on the whiteboard. Dr Moses further elaborated that by saying "*So, carbon dioxide and oxygen are some of the materials exchanged between interstitial fluids in the internal environment and external environment of the cell.*" As a result, some students were engaged in writing notes, indicating their involvement in the discussion and highlighting that feedback alongside writing can result in a MMO. Furthermore, this instance shows that when used appropriately, feedback can be used as a teaching strategy for enhancing students' pre-existing knowledge during an MMO.

MMOs resulting from a combination of writing and/or drawing and questions [WRTN+Q]

The SE combination of writing and/or drawing while posing a question had the fourth-highest frequency of 9 out of 63. This result indicated that this MMO type was among the least commonly manifesting MMO types in Dr Moses' lectures. This MMO type involved Dr Moses writing key terminology on the whiteboard while presenting a question. An example of this MMO type was seen in episode 5 of lecture 1, where a class discussion took place regarding osmotic states, specifically isotonic, hypertonic, and hypotonic states. Dr Moses initiated the discussion by asking a closed-ended question, "*Would there be*

a difference between the ones you put in pure water and the ones in a salt solution? In this case, students were expected to use the previous example of chips put in pure water to predict the outcome of chips placed in salt water. The students responded again in unison stating that the potato chips would not become turgid, indicating engagement. Dr Moses then probed further by asking another question, *"If they are not turgid, describe how will they be?"* while writing the term '*turgid*' on the whiteboard. This indicated that Dr Moses wanted the students to explore the different osmotic states explained earlier in the lecture. Even so, the verb 'describe' shows that this was still a lower-order question aimed at testing students' factual knowledge or understanding. Despite that, what was notable about this segment of the episode was that there was increased student participation. This could be attributed to Dr Moses' pedagogical choice of using every day or familiar examples of potato chips soaked in salt and/or pure water. That is why Koberstein-Schwarz and Meisert (2022) argue that students often struggle to engage with biological concepts due to their lack of relatability. Dr Moses expressed this viewpoint during the VSRI, emphasising that the use of potato chips example was intended to '…*make the content relevant to students*.' Therefore, this occurrence provides evidence supporting the critical role of everyday examples in fostering active engagement among students and for the manifestation of MMOs during learning.

MMOs resulting from a combination of a ***lecturer explanation and a question [LE+Q]***

The lecturer's explanations and questions were observed to have the fifth highest frequency, with 8 occurrences out of 63 instances at this level. These instances involved Dr Moses providing explanations while simultaneously posing questions. For example, during the first episode of lecture 1, a whole class discussion on the maintenance of the internal environment took place. Dr Moses explained that:

"*The focus of school curriculum is always mostly on us as humans as multicellular organisms. So, that's where the focus is, but here we are going beyond that. We start with what is happening with single-celled organisms okay, like your controversial annelida or paramecia. Now, what does this tell us uhmmm*? *Because of the difference in structure and in complexity, it means the way the internal environment is maintained will be in different forms with different organisms. In other words, if you got the paramecia and human beings, the ways that they maintain the internal environment is not going to be the same because one is just a single cell whereas the other one is made up of many cells…But the reason why the internal environment must be maintained constant is the same okay because the reactions that are taking place inside cell or inside that multi cells or at the tissue level, will only happen at certain conditions okay! So those conditions must be maintained.*

This explanation provided by Dr Moses demonstrated an awareness that he is teaching future teachers, and he aimed to extend their knowledge of the topic beyond what is covered in the secondary school curriculum. This knowledge, known as curricular saliency, is considered a component of Topic Specific Pedagogical Content Knowledge (TSPCK), as defined by Mavhunga and Rollnick (2013). According

to Kahn and Nyamupangedengu (2022), curricular saliency pertains to a teacher's awareness of where a topic fits within the curriculum and the purpose of sequencing and scaffolding that topic in a particular order. This occurrence further demonstrates that lecturer's knowledge of circular saliency impacts or shape manifesting MMOs.

During the explanation, Dr Moses employed what Allen and Tanner (2017) refer to as a rhetorical question, which is characterised by the lack of sufficient time for students to think or respond. This use of a rhetorical question was probably aimed at stimulating thinking and preventing student disengagement during the lengthy explanation, as evidenced by some students who were seen listening attentively to Dr Moses while others took notes. While explaining, Dr Moses mentioned "*We also talked about the fact that some of the materials are toxic okay, so they need to be removed*… *What do these toxic materials include, especially when we consider the Mammalia*?"
By doing so, Dr Moses drew upon his students' existing understanding of the different types of nitrogenous wastes with which they were familiar. Despite the use of the closed-ended question, the students responded about the types of nitrogenous waste which further evidenced their engagement during the manifesting MMO.

***MMOs resulting from a combination of a gesture and/or action and a* question G/A+Q**

Gestures and/or actions alongside questions had the same fifth-highest frequency of 8 out of 63 at this level, like the SE combination of ***[LE+Q].*** These results reveal that Dr Moses did not ask questions in isolation but based them on verbal and non-verbal cues which included explanations as well as gestures and/or actions. The SE combination of gestures and/or actions alongside questions was observed in episode 7 of lecture 2, where students were instructed to sketch an outline of the human urinary system, provide labels of the different structures and state their functions. After five minutes, Dr Moses requested the students to swap their drawings with their peers and report the structures that they had drawn. Dr Moses asked them *"What else is also there? What did they draw (pointing and looking at one of the student's drawings)? Look at it! Look at what they have drawn, what other structure is also there?* Dr Moses' series of questions could suggest that he wanted the students to thoroughly engage with their peers' drawings and exhaust all the different structures that they had drawn. The students mentioned the different parts such as the "*kidney*", "*bladder* and *urethra*" to mention a few. During the VSRIs, I asked Dr Moses why he wanted his students to exchange their drawings with peers. He said "*I knew that they would not actively participate if they had to report on their own drawings. So, I wanted them to be comfortable in just saying what their peers had drawn*". Dr Moses' response indicates that he used his knowledge of his students to deliberately use the T&L strategies of peer learning and/or collaborative learning to promote the manifestation of MMO that fostered active involvement among his students during this episode. This occurrence shows that prepared activities, knowledge of learners,

questioning and monitoring of students' work can be useful strategies for the manifestation of MMOs that can maximise students' engagement.

MMOs resulting from a combination of a lecturer's explanation and gestures and/or actions [LE+G/A]

The MMO type involving lecturer explanations accompanied by gestures and/or actions was found to be the least frequent, with only 4 instances out of a total of 63 at this level. This finding suggests that there was a limited number of MMO types that involved explanations alongside gestures and/or actions during Dr Moses' lectures. An example of such an MMO type was observed in episode 8 of lecture 2, where students were engaged in a second activity that required them to label the different parts of the human urinary system projected on the screen, as depicted in Figure 7.4 below.

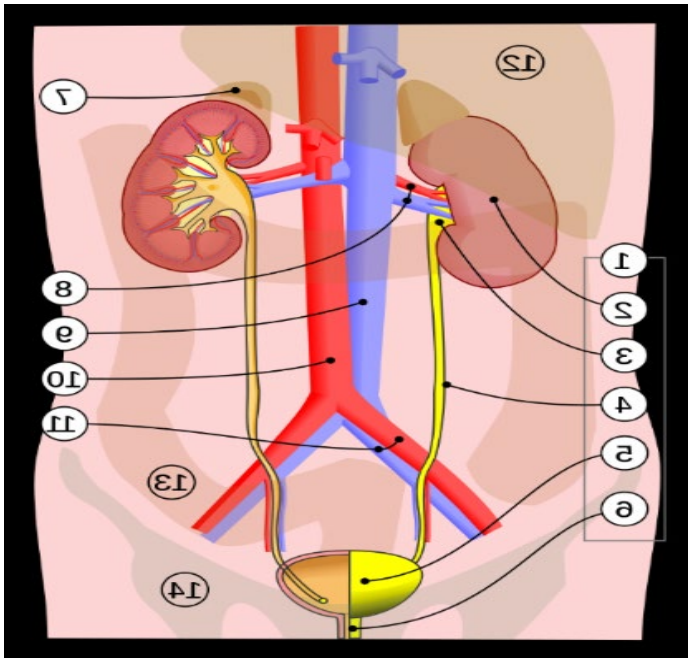


Figure 7.4 Outline of the human urinary system

During this activity, Dr Moses closely monitored the progress of the students seated in the front rows, who were seen engaged in the activity (signalled by students discussing and writing down labels). As Dr Moses was monitoring, he explained to the students that:

"…*We want to know what those different structures are (While looking and monitoring the students' drawings), we can't have a situation where we just have blanks, because all those structures have scientific names. For example, in the last activity, we spoke about the bladder temporarily storing the urine, it is there but I don't see it labelled...Once again do not refer to your notes, don't refer to the internet, right now the information I am only interested in what you know...*"

Dr Moses' explanation indicated his intention to evaluate the students' existing knowledge of the different organs involved in the human urinary system, without relying on external resources. However,

it became evident that some students had not yet commenced the activity. This observation suggests a possible lack of interest in participating among the students. This could be due to the similarity of this activity to the previous lecture as well as their familiarity with the content. Dr Moses spent considerable time on it even though he knew that his students knew this content, as evident from his statement "*Okay, now this is one we are more familiar with, and I can see your faces lighting up because now we are talking about the things that you know*." The results obtained align with those reported in Khan et al.'s (2016) study which revealed that teachers' inadequate selection of suitable learning activities and lesson sequencing can lead to a lack of student motivation in learning, resulting in the development of poor study habits and limiting future engagement opportunities. Therefore, these findings demonstrate the importance for lecturers to select suitable activities that will cognitively provoke and engage their students during MMOs.

7.2.2. Level 2 MMOs that resulted from the combination of three types of SEs

According to Table 7.2 provided above, Dr Moses' lectures at this level had a total of five different MMO types, with a total occurrence of 36 out of 108 instances (1 out of 3). This result shows a gap in the frequency of the MMO types that manifested at this level compared to level 1, which means that there were fewer manifestations of MMO types that accommodated students with **two or three learning preferences** in Dr Moses' lectures. The five MMO types comprised the following:

1. A gesture and/or action in combination with visual representations and lecturer explanations [GA+VR+LE]
2. A question in combination with gesture and/or action visual representations[Q+G/A+VR]
3. Feedback, lecturer explanation and writing and/or drawing [FDBK+LE+WRTN]
4. Lecturer explanation, writing and/or drawing and question [LE+WRTN+Q]
5. Feedback, gesture and/or action and visual representation [FDBK+G/A+VR]

In the sub-sections below, I further explain in greater detail and provided examples of occurrences of how four MMO types at this level manifested in Dr Moses' lectures.

MMOs resulting from a combination of a gesture and/or action, visual representations and lecturer explanations [GA+VR+LE]

The combination of gestures, actions, visual representations, and lecturer explanations was the most frequently observed occurrence, accounting for 10 instances out of 36 at this level. This result indicates that this MMO type appeared frequently in Dr Moses' lectures. An example of such an occurrence took place during episode 6 of lecture 2, during a whole class discussion centred around the function of the Malpighian tubules (an excretory organ) in insects depicted in Figure 7.5 provided below.

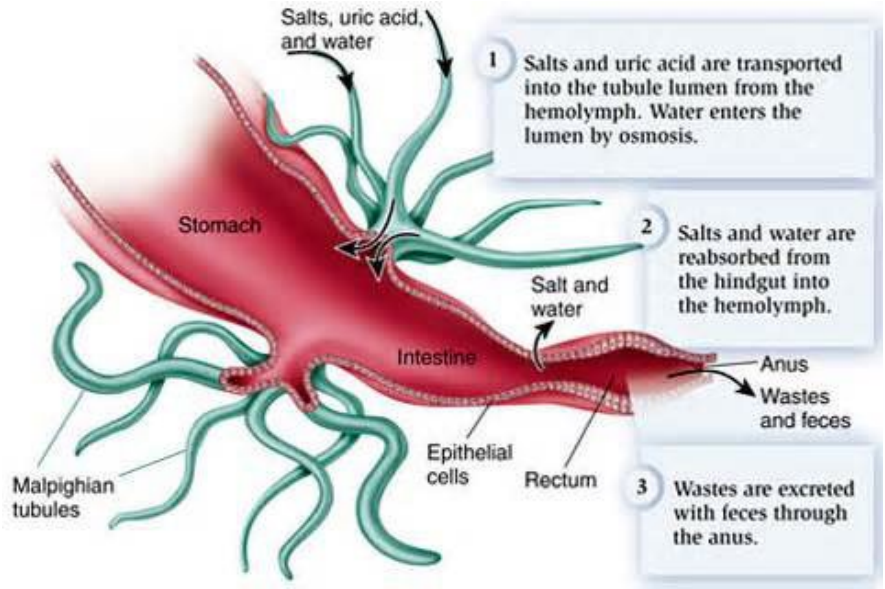


Figure 7.5 Malpighian tubules which are an excretory organ found in insects.

During the episode, Dr Moses explained:

"*That (Points at the image) will be your Malpighian body or your Malpighian tubules rather and these are found in insects, okay? I want you to note that these are found in insects. Like you can see there, not the whole structure has been indicated, what we have there are tubules that come from all over the body of an insect, and they open into the body cavity. In this case, we have a sort of the 'alimentary canal 'and we know that this is where the waste product will be taken out of through the anus*."

While Dr Moses was explaining the structure and function of the Malpighian body, he was pointing to the projected visual (Figure 7.5 above) to possibly help the students link the terminology to the correct structure and follow through with his explanation. During this episode, some of the students were seen in the video looking at the image while others were writing some notes which was evidence that the students were engaged during this MMO. Gerick et al. (2013) say that visual representations are crucial in focusing students during the explanation of abstract and complex biology concepts. However, Gerick et al. (2013) further caution that it is important for teachers to use these visuals mindfully, as they can sometimes lead to misunderstandings or perpetuate misconceptions among students. In Dr Moses' lecture, the image (Figure 7.5 above) showing just the Malpighian tubules or bodies might have contributed to this issue. Nevertheless, Dr Moses made sure to emphasise that these excretory structures are primarily found in insects so that the students do not develop any misunderstandings or misconceptions.

MMOs resulting from a combination of a question in combination with gesture and/or action visual representations[Q+G/A+VR]

The SE combination of a question with a gesture and/or action, and visual representations was the second most frequent occurrence, observed 8 times out of 36. An instance of this MMO type occurred again in episode 6 of lecture 2 during the whole class discussion on the Malpighian tubule. After explaining the structure and function of the Malpighian tubules, Dr Moses posed the following close-ended question to the students "*What is the difference between this (pointing at the image of the Malpighian tubules on the slide and the other two that we discussed?"* The other two excretory structures previously covered were the nephridial organs in annelids and meta-nephridia in earthworms. The students did not respond to Dr Moses' question, possibly indicating their lack of knowledge on the topic. However, some students were seen still focused on the projected screen, perhaps attempting to figure out the answer, therefore signalling engagement. Even so, during this episode, majority of students particularly those seated at the back, were engaged with their phones, indicating their lack of interest and/or general disengagement in the question. Instead of rephrasing the question, Dr Moses proceeded to explain to the students:

"*The other two, they come from the body cavity and the waste goes material straight into the external environment, okay. But, in this case, the tubules, they connect to the alimentary canal and the alimentary canal is responsible for taking the waste products through the anus*".

Although this situation could again be interpreted as a missed MMO, Dr Moses acknowledged during the VRSI that as much as he would like to wait for the students to respond and rephrase such questions for better engagement there are also issues of "*time constraints*". These findings suggest that students' lack of participation and time constraints can hinder the manifestation of MMOs during T&L.

MMOs resulting from a combination of feedback alongside lecturer explanations and writing and/or drawing [FDBK+LE+WRTN]

Feedback alongside lecturer explanations and writing and/or drawing had the second highest frequency of 8 out of 36. Such MMO types occurred when Dr Moses provided feedback alongside a lecturer's explanation while writing key points on the whiteboard. According to Scott and Mortimer (2012) when teachers offer explanations following feedback, it indicates their support for knowledge continuity during meaningful learning. This is because, during such learning instances, students are usually given an opportunity to establish connections between their existing knowledge and the new content being presented. This was the case in Dr Moses' lectures, as exemplified in episode 7 of lecture 1, during a whole class discussion on the role of excretion and osmoregulation. Before providing feedback, Dr Moses asked the students about the role of the skin in excretion. One student responded, "*The sweat contains water and salts, which means excess water and salt is removed from the body*." Dr Moses re-

stated the student's response while writing the keyword "*skin*" on the whiteboard. Many students were observed taking notes, indicating engagement during this manifesting MMO. While writing, Dr Moses further elaborated on his feedback to say, "*So, the skin plays a minor part in excretion, facilitating the removal of various substances from the body, including water and certain salts*." This occurrence is further evidence that Dr Moses continuously drew from his students' pre-existing knowledge to develop new knowledge of the topic during MMOs. Thus, highlighting that eliciting students prior knowledge plays a critical role in the manifestation of MMOs.

MMOs resulting from a combination of lecturer explanation alongside writing and/or drawing questions [LE+ WRTN+ Q]

Lecturer explanation alongside writing and/or drawing and questions had the third highest of 7 out of 36. This MMO type was observed when Dr Moses explained a concept while simultaneously writing and/or drawing on the whiteboard and posing a question to the students. An instance of this MMO type was documented in episode 1 of lecture 2, where Dr Moses revised the content from the previous lecture. During this episode, Dr Moses told the students that he had intended to draw a fish as depicted in Figure 7.6 below. While explaining his drawing to the students Dr Moses re-visited his drawing and added a fin as shown in Figure 7.6 below.

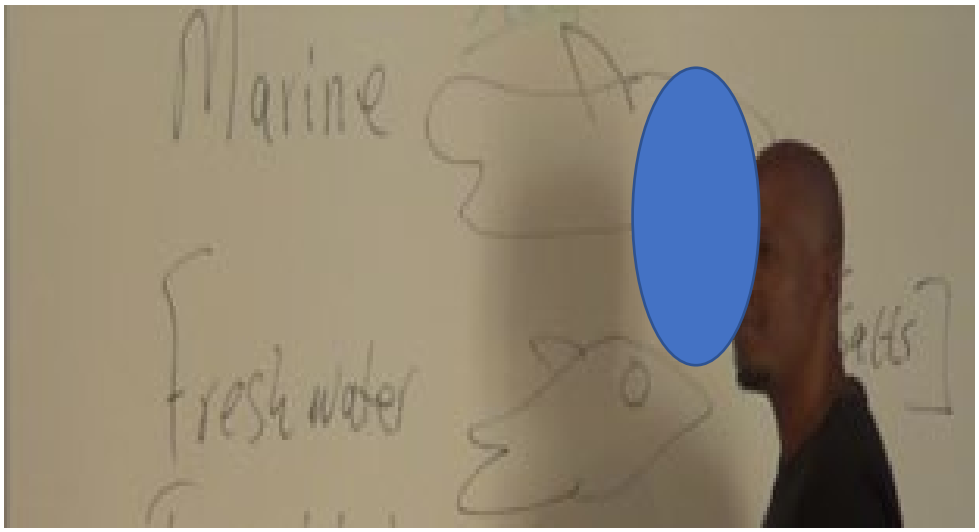


Figure 7.6 Free-hand drawings of a fish an organism found in marine and freshwater environments.

When Dr Moses referred to the drawn fish, most of the students were observed laughing, indicating emotional engagement during this episode. This aligns with Gerick et al.'s (2013) assertion that free-hand diagrams serve as improvisational strategies for visually representing complex information, resulting in memorable learning experiences and emotional stimulation. Dr Moses further explained that a fish is an organism found in a marine environment and asked the students "*Which organisms are found in freshwater?*" But none of the students responded. This silence suggests a conceptual gap in

ecological classification, which echoes Khan et al.'s (2016) findings that many students struggle specifically with differentiating between marine and freshwater environments. Thus, while the free-hand diagram successfully fostered affective visual engagement, the subsequent question revealed limited engagement with the disciplinary distinction between aquatic ecosystems. To elicit a response, Dr Moses rephrased the question, thus resulting in the manifestation of another MMO, by asking the students whether fish would be found in freshwater environments (a closed-ended question which required a word-one response). The students collectively replied by saying "*Yes*" indicating their agreement that fish can indeed be found in freshwater environments. However, Dr Moses did not further inquire about other examples the students could think of, which could have further ascertained the students' knowledge of organisms found in freshwater environments or lack thereof.

MMOs resulting from a combination of feedback alongside gestures and/or actions and visual representation [FDBK+ G/A+VR]

Feedback in combination with gestures and/or actions and visual representations had the lowest frequency of 3 out of 36. This SE combination had a component of a question that is known to promote active engagement among students. This was not the case in Dr Moses' lectures as most of these MMOs were not taken up by the students. This finding could be explained by the fact that most students were constantly on their phones as previously highlighted which are known to be distractive devices. The lecturer had not asked the students to Google the answers or use any application to collect any responses from them. Another potential factor associated with this lack of engagement could be linked to Dr Moses' questioning style, as most questions were mainly closed-ended and did not stimulate any higher order or critical thinking. For example, in episode of 5 of lecture 1 where there was a whole class discussion about the different osmotic states. During this episode, Dr Moses used the example of raw potato chips (an everyday example) placed in different environments (salty and pure water). Dr Moses' began by asking the students "*Now, we want to describe the inside of the potato that has salts inside but put inside pure water, the internal environment of the potato compared to what is happening outside. Do we say it is Hyper or Hypo?*" Again, the question asked by Dr Moses was closed in nature and required the students to just say one word. Some students responded in unison saying 'Hypo' Dr Moses provided feedback by saying "*It is going to be Hypo (pointing at the visual on the whiteboard) because there are more salt solutions in the inside compared to the outside"*. Dr Moses feedback shows that he simply agreed to the students' one-word answer that they sang in unison and elaborated on their response, rather than challenging them to justify their responses, which might have challenged them to think deeply about the content. These findings show that regardless of how complex an MMO may be its effectiveness is largely dependent on the quality of the question(s) asked and how these questions engage students with the content presented to them during lectures.

7.2.3. Level 3 MMOs that resulted from the combination of four types of SEs.

Table 7.2 above illustrates that there was a total of two MMO types that manifested in Dr Moses 'lectures at this level. Out of a total of 103 instances that manifested across the three levels, these MMO types were identified 9 times, accounting for less than 1 in 3 of the total occurrences. Notably, these MMO types were found to be less frequent in Dr Moses' teaching practice, meaning there were very few MMO types that accommodated students with three or more learning preferences. The two specific MMO types identified were as follows:

1. A lecturer explanation alongside writing and/or drawing, gesture and/or actions and visual representation [LE+WRTN+G/A+VR]
2. Feedback, alongside a question, gesture and /or actions and visual representation [FDBK+Q+G/A+VR]

In the sub-sections below, I explain in greater detail and provide examples of occurrences of how Dr Moses used these different SE combinations that resulted across the two lectures that were under observation.

MMOs resulting from a combination of a lecturer explanation alongside writing and/or drawing, gesture and/or actions and visual representation [LE+WRTN+G/A+VR]

The lecturer's explanation alongside writing and/or drawing, gesture and/or actions and visual representation had the highest frequency of 6 instances out of a total of 9. This finding indicates that Dr Moses made efforts to highlight crucial concepts during explanations by employing a combination of written and/or visual representations. For instance, this MMO type is again exemplified during episode 7 of lecture 2, where students were involved in an individual activity of drawing an outline representing the human urinary system, accompanied by the labelling of the structures and their respective functions. Subsequently, the students were required to verbally articulate all the different structures that their peers had represented in an open class discussion. One student mentioned the term "*Urethra*" and Dr Moses wrote this term on the whiteboard. Whilst he also explained (*Pointing at the slide showing human urinary system*) the function of the urethra "*as a tube which transports the urine out of the body.*" Some students were visibly engaged in the video, and this was evidenced by their attentive gaze toward the screen. It can be still argued that this MMO was not effectively utilised by Dr Moses because he immediately provided the students with an explanation of the function of the urethra, despite this aspect being part of their activity. Due to this, he might have lost out on a potential opportunity of gauging his students' understanding of the functions of the structures of the urinary system.

MMOs resulting from a combination of feedback, alongside a question, gesture and /or action and visual representation [FDBK+Q+G/A+VR]

The SE combination involving feedback alongside questions, gestures and/or actions, and visual representation, had a notably lower frequency of 3 out of 9. This type of MMO was observed once again in episode 7 of lecture 2, where students were drawing an outline representing the human urinary system, accompanied by the labelling of the structures and their respective functions. During the questions and answer segment, again one of the students mentioned a "*kidney*" as one of the structures that their peers had drawn. Dr Moses then provided the students with feedback by saying *"Oh, there is a kidney, and we said earlier that those remove excess water (scroll to the next slide to project image showing kidneys)"* Dr Moses' feedback further evidenced his ability to revisit previously covered concepts which is a fundamental component of cumulative learning advocated by Scott and Mortimer (2012). He asked the students "*The person sitting next to you have shown you what they have drawn, what is that they have drawn? What are some of the stuff in their diagrams apart from the kidney what else is there?"* This incident reveals that Dr Moses did not probe students' understanding of the functions of the structures, but it is evident that the T&L strategy that he used during this MMO fostered peer and/ or collaborative learning during the manifesting MMOs.

7.3. Discussion of the analysis and Conclusion(s)

In this chapter I presented an analysis of data from Dr Moses, the third case. The analysis identified thirteen distinct types of MMOs, which emerged from combinations of four social exchanges (SEs): talk, visual representations, witing and/or drawing, as well as gestures and/or actions. These MMOs were categorised into three levels of complexity.

Level 1 MMOs were again predominant in Dr Moses' lectures, mainly engaging students through visual representations paired with questions or lecturer explanations combined with writing or drawing. While these combinations often fostered student engagement, such as note-taking, answering questions, or examining visuals, their effectiveness appeared to be limited by the nature of the questions posed. Dr Moses frequently used closed-ended questions, which, although effective for eliciting quick responses, often lacked the depth to stimulate critical thinking or meaningful dialogue. Additionally, unclear phrasing in some explanations and questions led to gaps in students understanding, highlighting that how lectures explain and ask questions matters in the manifestation of MMOs.

Despite these challenges, Level 1 MMOs demonstrated the usefulness of visual and written aids in stimulating and enhancing student engagement. For instance, students interacted with diagrams and flowcharts depicting nitrogenous wastes and osmotic states, reflecting their value as scaffolding tools for abstract concepts during MMOs. However, missed opportunities to probe student understanding

through follow-up questions or justifications limited the potential of these MMOs to foster deeper student engagement.

Level 2 MMOs engaged students through a broader integration of SEs, such as combining visual aids with gestures and lecturer explanations or integrating feedback with writing and/or drawing. These combinations seemed to result in the manifestation of MMOs crucial for cumulative learning and knowledge reinforcement. For instance, feedback accompanied by explanations helped students connect prior knowledge with new concepts, as seen during discussions on excretory systems and their components.

However, challenges persisted. Students often displayed disengagement, particularly those seated at the back, due to repetitive activities and limited variation in questioning techniques. Time constraints also hindered Dr Moses from providing sufficient 'wait time' after posing questions, potentially compromising the depth of student engagement and/or responses during the manifesting MMOs. These results suggest that lecturer's ability to select appropriate activities, suitable teaching strategies and their knowledge of context and students all are critical in the manifestation of MMOs. Despite these challenges, peer-interaction activities, such as exchanging and analysing drawings of the human urinary system, showcased the potential of collaborative learning in fostering engagement and enhancing MMO effectiveness.

Level 3 MMOs manifested from the use of four different SEs which often involved component of gestures and/or actions as well as visual representations. The MMOs at this level usually offered the greatest potential for engaging students with three or more learning preferences. For instance, at this level, students engaged in MMOs that involved activities that required them to discuss, label diagrams and explain structures, fostering both individual and collaborative learning. However, missed opportunities to assess students' conceptual understanding through questioning seemed to hinder the full potential of these manifesting MMOs. In some cases, Dr Moses provided students with answers or explanations prematurely, bypassing chances to gauge or challenge student knowledge. Additionally, again the overuse of closed-ended questions in these complex combinations limited the opportunities for deeper students' engagements.

In summary, the analysis generally revealed that the manifestation of MMOs is shaped by the lecturer's pedagogical choices, knowledge of students, and ability to select relevant examples and activities. Dr Moses' lectures demonstrated that while the integration of diverse SEs has the potential to engage students, the quality of use and inclusion of clear explanations, varied questioning, and thoughtful activity design as well as their in-depth understanding of the content is critical in strengthening the manifestation of MMOs and student engagement.

In the next chapter, the analysis will turn to Dr Ellen's lectures, exploring the manifestation of MMOs in her lecturing of genetics and meiosis to fourth-year biology students.

Chapter 8:

Case 4: Dr Ellen

Topics: Genetics and meiosis

Class: 4th year biology pre-service teachers

8.0. Introduction

The previous chapter introduced Dr Moses who taught osmoregulation and excretion to 3rd year students. This chapter sets out to present Dr Ellen's background information and lecture overview. It presents findings from the analysis of Dr Ellen's lectures using the same data analysis processes detailed in Chapters 3 and 4. Finally, it provides insights that aim to answer the research questions that guided the study.

8.1. Dr Ellen's background information and lecture overview

Table 8.1 below presents a summary of Dr Ellen's background information and an overview of the two lectures under observation, to contextualise the results of this study. The information presented in Table 8.1 is further expanded upon in the subsequent sub-sections below.

Table 8.1. Dr Ellen's summarised background and lecture information

Age/Race/Experience	Qualification/s held	Teaching Philosophy	Class taught	Duration of the lectures in minutes		Number of PSTs taught	Content taught
				Lecture 1	Lecture 2		
African female. About 50 years old with more than 30 years of teaching experience.	BSc, PGCE, BSc Hons, MSc Ed, PhD	Constructivism and TSPCK used for planning	4th-year PSTs	90	45	60	Genetics

8.1.1 Content overview of genetics and meiosis and the challenges associated with teaching the topics

The inheritance of traits from one generation to the next via the process of reproduction ensures the continuity of life in all living forms on the planet and is studied through genetics. Genetics refers to the study of biological inheritance (Simon, 2021). Meaning that genetics is a study concerned with how traits or characteristics are passed from parents to offspring. Under the genetics topic, Dr Ellen covered the following: DNA structure and functions, meiosis and inheritance (both mono- and dihybrid).

The topic of genetics, particularly in the context of teacher education, has been extensively researched since the 1980s to the present day (see Thörne & Gericke, 2013; Pearson & Hughes, 1988). As a result, extensive knowledge exists about the teaching of genetics, especially concerning the challenges leading to students' misconceptions, confusion and/or misunderstandings (Mustami, 2016). Some studies (e.g. Pearson et al., 1988; Altunoglu et al., 2015) have identified terminology associated with genetics as one of the sources of challenges in teaching and learning this topic. An example of such terms involves chromatin, chromatids, allele, locus, homologous, homozygous, heterozygous, dominant, co-dominate and recessive to mention a few. This extensive collection of terms is often used to explain abstract concepts, products and/or process of genetics. Consequently, students often confuse some of these terms that seem and sound alike, for example, allele-locus, homozygous-homologous, chromosomes-chromatids, and many others (e.g. Mdolo & Mundalamo, 2015; Thörne & Gericke, 2013). Nyamupangedengu (2015) states that students often struggle with these terms because they do not use them in their everyday lives, therefore, lecturers are required to explicitly spell out and emphasise these terms during their lectures.

Another issue that is closely linked to terminology is that students often fail to establish relationships that exist among some of the earlier-mentioned terms (see: Thörne & Gericke, 2013). For example, a study conducted by Mdolo and Mundalamo (2015) in a Malawian secondary school revealed that most learners struggle to see the link between a gene, DNA and chromosome. According to Nyamupangedengu (2015) one of the reasons for this challenge stems from the textbooks that the students are exposed to which often fail to clearly explain or show the relationships among these genetic concepts. On the other hand, Bahar et al. (1999) also argues that the other problem is that these constructs belong to distinct biological organisations (the micro, the macro, and the symbolic) which teachers often fail to incorporate in their explanations. According to Bahar et al. (1999) the micro level refers to the microscopic phenomenon that cannot be observed with the naked eye but can be studied through various types of biological treatments such DNA extraction or staining animal or cheek cells with iodine solution. On the other hand, the macro level involves large entities of characteristics that can be observed with the naked eye such as eye colour and height (Bahar et al., 1999). Also, the symbolic level involves symbols used to describe or depict the genetic structure such as uppercase letters to represent dominant alleles (WW) or lowercase to represent recessive alleles (ww). Bahar et al. (1999) say that if teachers clearly foreground these various levels in their explanations, they can be able to support their students' understanding of the complex relationships that exist among key genetic concepts.

Meiosis

Figure 8.1 below shows that the products of meiosis I and meiosis II, result in the formation of two and four daughter cells, respectively, each containing a haploid number of chromosomes. Meiosis I involves

a preparatory stage called in interphase, which does not occur in Meiosis II. Both meiosis I and II involve four stages as well as cytokinesis similarly to the process of Mitosis (detailed in Chapter 6). Consequently, the meiotic processes and products play a crucial role in contributing to genetic diversity, which is vital for the continuity of sexually reproducing organisms.

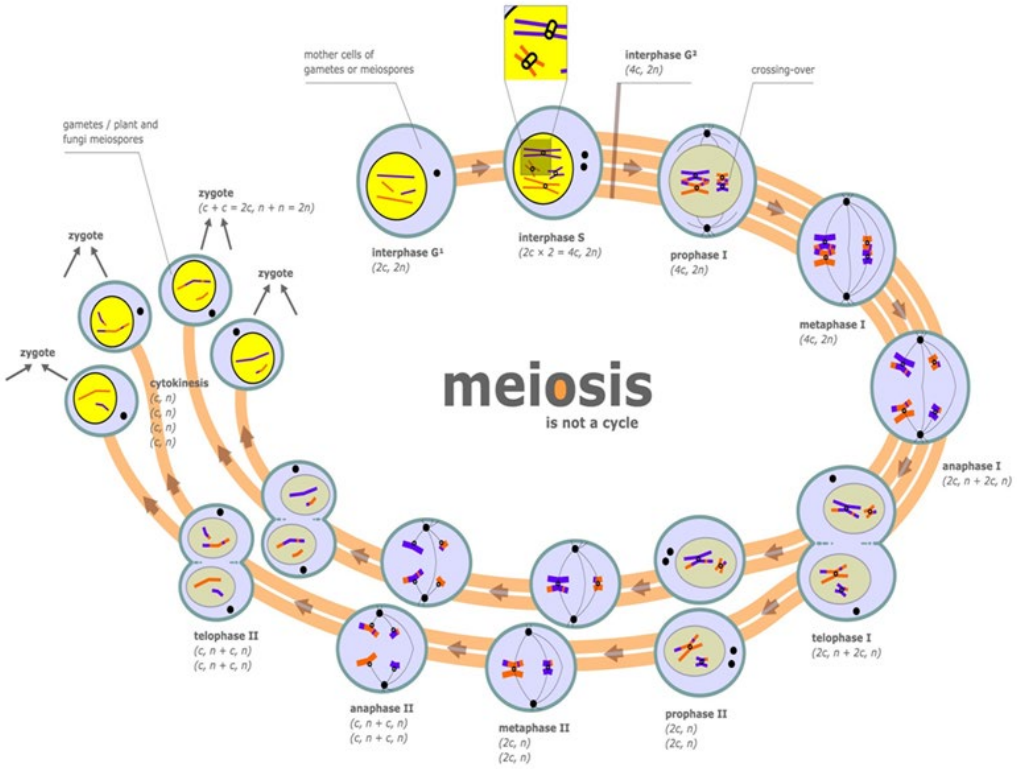


Figure 8.1 Processes and Products of Meiosis (Retrieved from Dr Ellen's lecture 2 slides)

With regards to meiosis, a study conducted by Tolman (1982) in a high school context identified challenges students faced when linking meiotic events, like independent assortment and segregation, to Mendelian genetics when solving problems. Students tended to erroneously assign two alleles to each gamete, resulting in offspring with four alleles for each trait. This highlights the need for teachers to help students establish such links as it may be difficult for students to do so independently (Nyamupangedengu, 2015).

8.1.2. Context of the lecture, resources and technologies used by Dr Ellen

Like Drs Molly and Moses, Dr Ellen also conducted lectures for a manageable group of 60, 4th-year students in her designated lecture venue. These 4th-year students had already completed two full years of natural sciences lectures and one full year of biology which is now their major or subject of specialisation. Like the previous cases, Dr Ellen's lecture venue was a lecture theatre equipped with a screen at the front and students seated in closely spaced parallel rows, with the lecturer positioned at the front of the venue. Dr Ellen also used prepared PowerPoint slides as the primary means of delivering information and used the school's LMS called Sakai to upload all her course content. However, unlike

the other three Drs, Dr Ellen also utilised additional resources and/or materials in her lectures which included the use of a DNA model, household materials such as strings and prepared handouts.

8.2. Presenting the findings

Table 8.2 below provides a summary of the SE combinations and the MMO types that manifested in Dr Ellen's lectures. From the table below, it can be deduced that there was a total of sixteen MMO types that were identified across the two lectures and were categorised into three distinct levels. Among these MMO types, five were observed at level 1, comprising 44 instances out of a total of 128, which accounted for approximately 34% of the overall occurrences across all three levels. These findings suggest that a relatively smaller proportion of level 1 MMO types were designed to cater to students with one or two learning preferences. On the other hand, at level 2, six MMO types were identified, constituting 53 instances out of 128 across the three levels. This result implies a higher proportion of 41% MMO types manifesting in Dr Ellen's lectures that accommodated students with two or three learning preferences. Five out of sixteen MMO types were identified at level 3, making up 31% of the total across all three levels. These results indicated that there were an equivalent number of MMO types in both levels 3 and 1. However, the occurrence of 24 out of 128 at level 3 suggests that there were not as many MMO types observed at this level that accommodated the needs of students with three or more learning preferences.

Table 8.2 Summarised findings of the types of SEs and MMOs that manifested across the three levels in Dr Ellen's lectures.

Levels of MMOs	Description of each level	Types of MMOs manifesting across the two lectures	Frequency of type of MMO across lectures	Manifesting forms of engagement across the two lectures
1	**Combination of two types of SEs**	1 Q+ FDBK	**14**	**-Most students are looking at the screen** **-Some students are looking at the demonstrations and engaged** -Most students have **their hands raised** and some are asking questions **-Most students are making notes** **-Most students are listening to the lecturer and engaged** **-Most students are discussing the questions posed with their peers and some not discussing** **- Some students are seen laughing**
		2.LE+Q	**13**	
		3. LE+G/A]	**7**	
		4. LE+VR	**4**	
		5 FDCK ANLG	**4**	
		Proportion of the total frequency of MMOs	**44**	
		Proportion of the total (in %)	**34**	
2	**Combination of three types of SEs**	1.ANLG+G/A+Q	**14**	**-Most students are looking at the screen** **-Some students are looking at the demonstrations and engaged** -Most students have **their hands raised** and some are asking questions. **-Most students are making notes** **-Most students are listening to the lecturer and engaged**
		2.GA+VR+LE	**12**	
		3. Q+ FDCK+G/A	**10**	
		3 Q+FDCK+LE	**9**	
		4. FDBK+G/A+WRTN	**4**	
		5. LE+G/A+WRTN	**2**	
		6. FDBK+ G/A+VR	**2**	

		Proportion of the total frequency of MMOs	**53**	**- Most students are discussing the questions posed with their peers and some not discussing**
		Proportion of the total in (%)	**41**	**- Some students are seen laughing** **--Some students are seen engaging with the lecturer**
3	**Combination of four types of SEs**	1.LE+G/A+VR+Q	**12**	**-Most students are looking at the screen** **-Some students are looking at the demonstrations and engaged** -Most students have **their hands raised** and some are asking questions. **-Most students are making notes** **-Most students are listening to the lecturer and engaged** **-Some students are discussing the questions posed with their peers** **- Some students are seen laughing** **--Some students are seen engaging with the lecturer**
		2. Q+ FDBK+G/A+VR	**7**	
		3. LE+G/A+VR+ANLG	**5**	
		4 FDCK+LE+G/A+VR	**4**	
		5. LE+WRTN+G/A+Q	**3**	
		Proportion of the total frequency of MMOs	**31**	
		Proportion of the total in (%)	**24**	

8.2.1. Level 1 MMOs that resulted from the combination of two types of SEs

Table 8.2 above revealed that a total of sixteen distinct MMO types were observed in the two lectures. From these sixteen SE combinations, a total of five level 1 MMO types were identified and had a combined frequency of 44 out of 128 instances across all three levels. The five MMO types consisted of the following:

1. A question and feedback [Q+ FDBK]
2. A lecturer explanation and a question [LE+Q]
3. A lecturer's explanation and a gesture and/or action [LE+G/A]
4. A lecturer explanation and a visual representation [LE+VR]
5. Feedback and an analogy [FDCK+ANLG]

In the subsequent sections, I explain how these five MMO types manifested in Dr Ellen's two lectures.

MMOs resulting from a combination of a question and feedback [Q+FDBK]

As indicated in Table 8.2 presented above, the most observed type of MMO results from the SE combination of a question and feedback, which occurred 14 times out of the total 44 instances at this level. This result suggests that Dr Ellen mainly asked questions and provided feedback, which alludes that there was most MMOs that fostered some sort of dialogic exchange of ideas in her lectures. For instance, during episode 4 of lecture 1, after Dr Ellen had taught about DNA, genes, and chromosomes, she instructed the students to engage in a five-minute discussion in pairs based on the questions depicted in Figure 8.2 below.

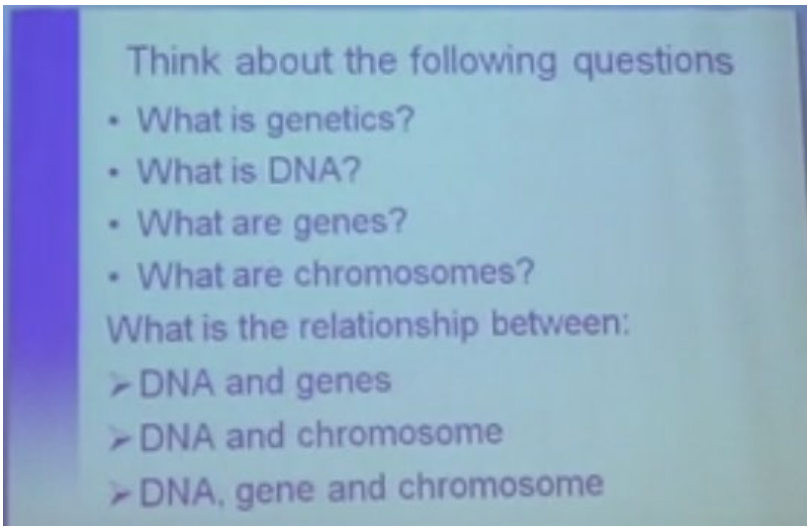


Figure 8.2 Activity 2 was used in lecture 1 to facilitate pair and whole class discussions DNA, genes and chromosomes.

This activity promoted peer-to-peer or student-to-student interactions, as evidenced by most students who were seen in the video engaging in discussions with one another. After the five-minute pair discussion, Dr Ellen asked the students if they can now proceed to the whole class discussion "*...just to make sure we have the same understanding*." This statement reveals that Dr Ellen used the activity to assess her students' comprehension of the already covered concepts of DNA, genes, and chromosomes, as well as their interrelationships before proceeding with the lecture. Dr Ellen then posed the question, "*If I ask you what DNA is, what would you say?*". This question was open-ended in nature because it encouraged students to express their understanding of DNA in their own words. One student responded by stating, "*DNA is a collection of genes with different characters or umh yah*!" Dr Ellen acknowledged and re-voiced the student's response and proceeded to inquire from the other students if they had "*Anything else to add there?"* This question demonstrates her invitation for contributions from the students or her prompting students to actively participate in the discussion further, thus resulting in another manifestation of a MMO. Another student responded and said, "*Each gene has unique features."* Dr Ellen provided corrective feedback by suggesting, "*Let's end at the collection of genes. So, instead of saying 'features', say a collection of genes with different features, but 'features' is also not the right word there.*" From the feedback, it can be seen that Dr Ellen's continuously said 'let's' which according to Scott and Mortimer (2012) indicates a joint collaboration between the teacher and students during meaning making process. Scott and Mortimer (2012) argue that teachers' use of inclusive terms like 'we' and 'us' serve as foundational requirements for building trust and a conducive T&L space that freely permits the joint sharing of ideas during meaningful T&L. This claim was further supported by a student who interjected and said, "*Let's say genetic information!"* with excitement Dr Ellen again acknowledged this contribution and remarked, "*Yes! Yes, genetic information! Well done! So, it is a collection of genes.*" As exemplified in **extract A** below, Dr Ellen consistently probed and provided feedback throughout the interaction and asserts

Estaji's et al. (2023) argument that questions and feedback are central components for promoting dialogic interactions between lecturer and students during meaningful discourse.

EXTRACT A

1.	*E: Yes, DNA is a collection of genes, anything else?*
2.	*S 12: (interjects) with unique features*
3.	*E: yes, it is the collection of genes with unique genetic information. Yes, then there we agree! Come on what do you say? (Probing the Ss) Yes! (Pointing at the S with their hand up)*
4.	*S 10: We said they are the kind of sugar that generates genetic material*
5.	*E: A sugar that generate genetic material?*
6.	*S 10: Yahhh*
7.	*E: it is not a sugar so maybe you can say it is a molecule. There is a sugar that is there to form DNA, but it is not sugar itself (correcting Ss incorrect thinking/misconception/misunderstanding). So, you are referring to carry genetic material, what do you mean by genetic material? (probing)*
8.	*S 10: It refers to a gene.*
9.	*E: So, it would be better to specific and say that DNA is a molecule that carries genes. Okay, any different answers that… so DNA is a molecule that is correct which carries or has a collection of genes like she said and with unique genetic information. Okay and then, what are genes? What are genes? (Repeats the question). There, yes!*
10.	*S 14: The sequence of nitrogen bases on a DNA strand.*
11.	*E: the sequence of nitrogen bases on a DNA strand (As she repeats the Ss' response, she seems to be thinking about it) Correct! So, it is a specific sequence of nitrogen bases on a DNA strand. What does that specific sequence do for us to be able to label it as DNA?*
12.	*S 15: It carries genetic information.*
13.	*E: it carries genetic information for what? (Probing). The genetic information is used for what?*
14.	*S 15: For…. For…ummh the making of proteins maybe (sounding unsure)*
15.	*E: For the formation of the protein. Any genetic information on DNA is for the formation of a protein. So, if we go further from what she said, it is a sequence of DNA bases on a DNA strand is responsible for the formation of protein. Otherwise, we would say the whole DNA is a gene but only specific sequence that codes for a protein becomes one gene. So, if we have 10 specific sequences it means we have ten different genes on a DNA strand that are responsible for ten different proteins. Are we together there?*
16.	*Ss: (some saying yes)*
17.	*E: So, what is a chromosome? This one should be easy now. What is a chromosome? (Repeats the question)*

Extract A above demonstrates the active engagement of the students, as evidenced by their diverse responses, even when they were uncertain of their answers, as exemplified in line 14 above. This active engagement can be explained by the fact that students were given sufficient time to discuss their ideas with their peers before discussing ideas in a whole class discussion, and this became an area of interest during the VSRI and Dr Ellen mentioned that:

"Sometimes you think you have understood, but when you try to explain you find it very difficult to do that, so verbalising helps even you as an individual to organise your own thinking. If you can explain to someone it's really a way of showing that you have understood. Sometimes you have not understood so as you try to think through to put across your thoughts you are actually reorganising…also an opportunity for the person you're talking to say, "No I thought I understood this" and then you see the mistakes and the misunderstanding can be clarified if it's verbalized. So, the reason why I started with pair work and then a whole class discussion is that normally I see students don't want to just answer, they are afraid of wrong answers, and they are afraid of their English so pair work sort of prepares them to have that confidence. Firstly, because they say, "This is not my answer and say in our group, this is what we discussed". So, it sort of removes pressure or fear of saying "What if the answer is wrong?" because now it's a collective answer…"

Dr Ellen's response aligns with Chatila and Husseiny's (2017) claim that collaborative learning has the potential to enhance students' confidence as they are afforded the opportunity to share, organise, and re-organise their ideas with their peers. According to Chatila and Husseiny (2017) when students verbalise their responses, it is the only time teachers can gain insight into the type of meaning (s) that their students are formulating regarding the taught concepts. So, it is important for teachers to engage with their students' responses and provide positive and corrective feedback to foster comprehension of concepts as well as active engagement. These findings reveal that the active participation of students in MMOs is not solely influenced by questions and/or activities that are used in lectures, but it is founded on teacher's knowledge of their students (a component of PCK/TSPCK) (Mavhunga & Rollnick, 2013). This is because, the knowledge of students often provides lecturers with guidance as to which appropriate methods to select during their planning in order to engage their students effectively in MMOs (Mavhunga & Rollnick, 2013).

MMOs resulting from a combination of lecturer explanation and a question [LE+Q]

The SE combination of lecturer explanations alongside a question had the second highest frequency of 13 out of 44 instances at this level. This suggests that this SE combination was one of the most commonly occurring MMO types in Dr Ellen's lectures. An illustrative example of this MMO type occurred during episode 8 of lecture 1, during a consolidative whole-class discussion that followed a pair activity on DNA, genes, chromosomes, and their relationship. In this episode, Dr Ellen explained to the students that:

"So, we are saying that each gene contains the information for the production of a specific product and that product is a protein. I want you to note here that one of the huge misconceptions that we have here is that a gene is responsible for the formation of a hand, for the formation of a nose, of ears, hands and so on."

From the explanation above, Dr Ellen addressed what she regarded as a huge misconception pertaining to the role of genes in the formation of traits. Dr Ellen emphasised that a gene is not directly responsible for the development of body features such as hands, noses, or ears, which is a widely documented misconception in the field (Etobro et al., 2017; Mustami, 2016). The term "misconceptions" refers to concepts that students perceive in a particular way but are not scientifically proven to be accurate" (Etobro et al.,2017, p.121). According to Nyamupangedengu (2015), knowing the type of misconceptions that students bring to the teaching and learning context is an identifier of the lecturer's knowledge of their students, a component of TSPCK (Mavhunga & Rollnick, 2013) as previously mentioned. During the VSRI when asked about how she knew most of the misconceptions surrounding the topic of genetics she said:

"*When planning to teach the topic I did not only use textbooks, but I read a lot of research articles which helped me understand the challenges, misconceptions and some strategies that I can use to effectively teach this topic…"*

This could be the reason why Dr Ellen explicitly mentioned this misconception during her explanation as a means of diagnosing it.

Following the explanation, Dr Ellen then asked the students "*Why is that statement wrong? If we say that each gene is responsible for the production of each feature that we have? Why is that wrong?"* According to Shanmugavelu et al (2020) this type of question is a higher-order question as it requires the students to reason and justify their responses. This open-ended question was also aimed at eliciting students' ideas about the misconception and determining whether they held this misconception. During the ensuing discussion, one student expressed "*I don't think it is responsible for the reproduction of that"* Dr Ellen probed further to ask, *"What is it that they are responsible for?*" The student elaborated further saying *"It tells you what the feature is, plus it tells you if you have big hair, or you have green eyes, but I don't think it produces the actual features."* Dr Ellen picked up that the student also had a misconception and further asked "…*What does the gene do?*'. One of the students explained that "*The gene is responsible for the production of a specific protein that has the labels of a particular trait."* All the students' responses indicated their engagement during this manifesting MMO. Again, this became another area of interest during the VSRI and Dr Ellen was asked about why she probed the students about this misconception after highlighting it to them, rather than simply explaining it and then proceeding with the lecture. She explained that:

"…Because I think if they verbalise their erroneous thinking and then I probe I will hopefully be able to correct it, because if I just explain they may package it side by side or they may just go back to their initial thinking…"

These findings reinforce the assertion made by Mustami (2016) that educators must be mindful of their students' potential misunderstandings regarding specific subjects. By doing so, they can effectively identify and address these misconceptions during MMOs, thus facilitating more meaningful learning experiences. These results revealed that, lecturers should not solely depend on textbooks as their main planning resources, as these materials often do not alert them of the potential misconceptions or learning challenges faced by students when learning the topic. To overcome these limitations, lecturers should also incorporate research articles into their preparation process, as a means of enriching and expanding their students' understanding of content and strengthening their pedagogic expertise. That is why Jaipal (2010) says that effective T&L is grounded in sound research.

MMOs resulting from a combination of lecturer explanation and a question [LE+G/A]

The combination of lecturer explanations alongside gestures and/or actions exhibits the third-highest occurrence of 7 out of 44 at this level. This finding indicates that Dr Ellen did not frequently incorporate gestures and/or actions when providing explanations as much in her lectures. An example of an occurrence of such an MMO type was observed in episode 6 of lecture 2, where a whole class discussion followed an activity where students had to discuss in pairs the various cellular activities that occur in the early prophase of meiosis I. Following a verbal summary of student responses, one student requested Dr Ellen to "*…please explain the difference between chiasma and crossing over?"* This incident serves as evidence that the student was actively engaged in this MMO as they were able to recognise their own gaps in their understanding between chiasmata and crossing over. This occurrence provides support for the findings of Thörne and Gerick (2013) who argue that students frequently conflate these two processes or concepts, thus negatively contributing to challenges in the T&L of genetics. Dr Ellen used this opportunity to clearly and briefly explain that *"Crossing over is the exchange of genetic information between the maternal and paternal homologous chromosomes. While chiasma is just a point where they cross…".* Whilst explaining, Dr Ellen also illustrated the concepts using her fingers, as depicted in Figure 8.3 below.

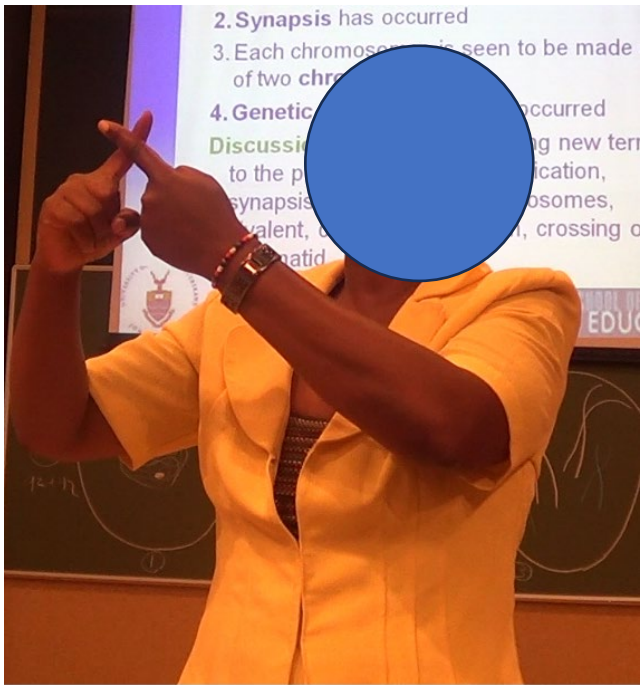


Figure 8.3 Dr Ellen demonstrates using her fingers the process of crossing over between two homologous chromosomes.

This demonstration seemed to capture the students' attention, as most of those them were seen writing or taking notes, while others seemed to redirect their focus to observe her hand movements in the video, which all evidenced their engagement during the manifesting MMO. This aligns with Taylor's (2012)

assertion that demonstrations and bodily gestures serve as effective visual stimuli for eliciting students' interest as it allows them to visually see the abstract phenomena being explained.

Dr Ellen further provided a detailed explanation, stating that:

"…*sometimes the paternal and maternal chromosomes may form a chiasm but crossing over may not occur. Crossing over is when one part of the homologous breaks and joins the other one and this one joins the other one, so there is an exchange of sections of each chromosome and that is crossing over. Chiasma is just that point where they join."*

Whilst explaining Dr Ellen continued to demonstrate the process of crossing over using her fingers. The students further asked several other follow-up questions based on the explanation such as "*Mam, I heard you say that homologous chromosomes may have same genes?*" "*ohh they have similar genes. So how do we have the same gene if one comes from the mother and the other one comes from the father?" "ohhhh so they carry one gene for each thing??"* These follow-up questions and the phrases "*ohh.."* indicate that the student experienced "light bulb moments" or clarity, which suggests that the explanations provided by Dr Ellen helped them address their initial misunderstandings and/or confusions. This occurrence supports Chin and Osborne's (2007) that:

"*For students learning science, their questions have the potential to (a) direct their learning and drive knowledge construction; (b) foster discussion and debate, thereby enhancing the quality of discourse and classroom talk; (c) help them to self-evaluate and monitor their understanding; and (d) increase their motivation and interest in a topic by arousing their epistemic curiosity*." (p.3)

These findings also affirm Scott and Mortimer's (2012) assertion that interactive and dialogical communicative approaches during science T&L play a critical role in the development of students' understanding. This MMO demonstrates that it is not only questions that prompt students' thinking but clear explanations alongside demonstrations especially those that emphasise the relationship that exists among concepts can enable students to grasp abstract concepts more effectively.

MMOs resulting from a combination of a lecturer explanation and a visual representation [LE+VR]

The SE combination of a lecturer explanation alongside a question had the lowest frequency of 4 out of 44 at this level. This result suggests that Dr Ellen did not frequently provide explanations based on visual representations during her lectures. An example where this MMO type manifested was again during episode 8 of lecture 1 where Dr Ellen was consolidating a pair activity that the students had completed about DNA, gene, chromosome and their relationship. During the episode, Dr Ellen earlier projected an image showing a diagram of how a chromosome is typically represented in a textbook called Focus (normally used in South African secondary schools) as depicted in Figure 8.4 below.

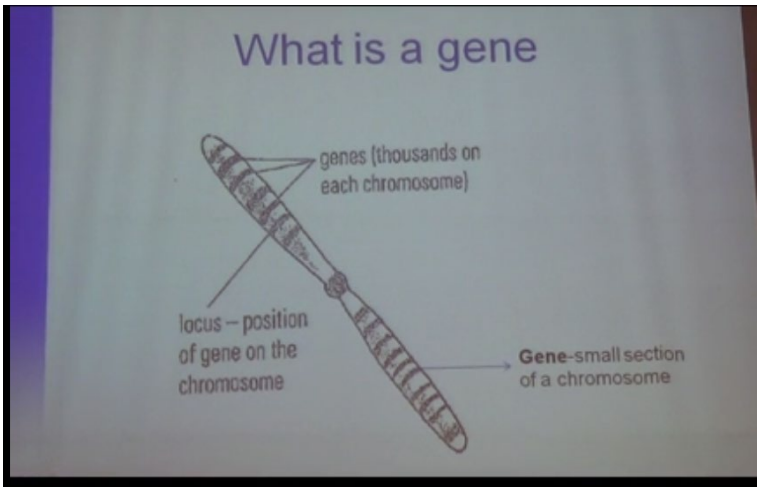


Figure 8.4 A chromosome (Extracted from a textbook called Focus)

The visual represented in Figure 8.4 above shows that the visual was clearly labelled and was used by Dr Ellen to establish the relationship between a gene and a chromosome. She explained that:

"*This diagram (talks about it without pointing at it) is from Focus, it is a simplified diagram of a chromosome. So, you will see in textbooks saying a small section of a chromosome is a gene, that statement is correct, but it may be wrong if you don't know that what we have in that chromosome is DNA. And from the diagram, we are saying that there are thousands on each chromosome so there are a lot of genes on each chromosome.*"

From the explanation, Dr Ellen told the students that the diagram of a chromosome that they see is from Focus, one of the biology-prescribed books used in some South African schools. This became one of the areas of interest during the VSRI and Dr Ellen was asked about what interested her in using this image from this specific textbook, was it because it was used in high schools or was there an aspect that interested her about this image? Dr Ellen mentioned that:

"...so if you look in the textbook there's no reference to DNA because of that the DNA structure and function are in a different chapter. And it is discussed and it ends there and here they just start with the chromosomes and there's no mention of DNA. And this is why students find it difficult to find the link between the concepts and actually the link is never there. There is no mention of DNA molecule in this chromosome so I wanted to highlight or emphasise enough to say this diagram does not make reference to DNA at all, but the chromosome is a highly coiled structure of DNA...So, I wanted to highlight how the content is represented in the textbook which is the source of challenges that learners face in understanding the relationship between these components."

Dr Ellen's response supports Nyamupangedengu's (2015) argument that students rarely encounter genetic terms beyond the confines of the classroom. Additionally, some textbooks they use fail to establish connections and important relationships between these concepts, thus leading to confusion among students. Consequently, it becomes imperative for biology lecturers to offer clear explanations

supported by visual demonstrations to establish these relationships to enhance students' understanding, as demonstrated during this MMO.

Dr Ellen's response also indicates her understanding of curricular saliency (a component of TSPCK- explained in Chapter 7) related to the genetics topic. She provides evidence that she knew that DNA is taught in a separate chapter from the one that covers the concepts of genes and chromosomes. Thus, she deliberately used the image of the chromosome from the textbook to emphasise the relationship between gene-DNA-chromosome. Moreover, these results corroborate Sanders and Makotsa (2016)'s findings that high school textbooks often contain errors and misconceptions regarding various biology topics. Therefore, lecturers must possess a robust knowledge of their subjects of specialisation, including knowledge of curricular saliency, to be able to identify and address issues of topic sequencing presented by textbooks and promote MMOs that may caution again implicit misconceptions contained in such textbooks.

MMOs resulting from a combination of feedback and an analogy [FDCK+ANLG]

The SE combination of lecturer feedback alongside an analogy also had the lowest frequency of 4 out of 44 at this level, which suggests that it was one of the MMO types that was not commonly used by Dr Ellen. An example of such an MMO type again occurred during the pair activity consolidation phase in episode 8 of lecture 1. While Dr Ellen was explaining and trying to give the students a picture of how big a DNA molecule can be. One student asked, "*Okay maybe I am thinking a little bit too far now ma'am, but can I just ask?*". This evidence that the student was involved during the MMO and actively listening and thinking about their own understanding, thus asking a question upon realising their gaps. Dr Ellen permitted the student to ask even though the student had interjected whilst she was still explaining. The student then proceeded to ask "*So, the mRNA and the gene have some sort of connection…?"* Dr Ellen then provided feedback by saying, *"…mRNA is just a small section of the DNA and then it carries the information into the cytoplasm where protein synthesis occurs..."* The student responded saying *"Ohhh so, mRNA has genes as well…"* To further strengthen the student's understanding, Dr Ellen used an analogy and said "*Yes mRNA has genetic information, it's like a letter we can't carry the whole book we just take one sentence, and you deal with that. So, we can say the whole book is the DNA and the one sentence is the genetic information."* The student responded by saying *"Thank you ma'am that makes sense…".* This suggests that the student was able to make sense of the analogy offered by Dr Ellen which compared DNA to the whole book and the gene as a sentence from the book, thus placing emphasis that mRNA is a small section of DNA. Sezer (2022) explains analogies as a comparison between two objects or things that illustrates how they are in some sense structurally similar. These findings suggest there is a need for the incorporation of analogies during MMOs as they are important representational tools that can be used to explore new abstract concepts by building on students' familiar or everyday knowledge (Keri, 2022).

8.2.2. Level 2 MMOs that resulted from the combination of three types of SEs

Table 8.2 above revealed that a total of sixteen different MMO types were observed in the two lectures. From these sixteen SE combinations, seven MMO types were identified at level 2 with a combined frequency of 53 out of 128 instances at this level. These results suggest that many of the MMO types that manifested in Dr Ellen's lectures accommodated students with **either two or three learning preferences.** The seven MMOs consist of the following:

1. An analogy alongside a gesture and/or action and a question [ANLG+G/A+Q]
2. A gesture and/or action alongside a visual representation and Lecturer Explanation [GA+VR+LE]
3. A question alongside feedback gesture and/or action and [Q+ FDCK+G/A]
4. A question alongside feedback Lecturer explanation and [Q+ FDCK+ LE]
5. Feedback alongside a gesture and/or action and writing [FDCK+G/A+WRTN]
6. Lecturer explanation alongside a gesture and/or action and writing and/or drawing [LE+G/A+WRTN]
7. Feedback alongside a gesture and/or action and visual representation [FDBK+ G/A+VR]

In the following sections, I explain in some detail with examples of how these seven MMO types manifested.

MMOs resulting from a combination of an analogy alongside a gesture and/or action and a question [ANLG+G/A+Q]

Table 8.2 above reveals that an analogy alongside a gesture and/or action and a question had the highest frequency of 14 out of 53 at this level. This finding indicates that Dr Ellen primarily used demonstrations, analogies, and questions to promote the manifestation of MMOs that catered to students with two or three learning preferences. An example of this MMO type was observed in episode 4 of lecture 1, where Dr Ellen used a demonstration and analogy involving brown and white strings to illustrate the relationship between a gene and DNA as shown in Figures 8.5 and 8.6 below.



Figure 8.5 Dr Ellen's demonstration of a gene using coloured strings tied together

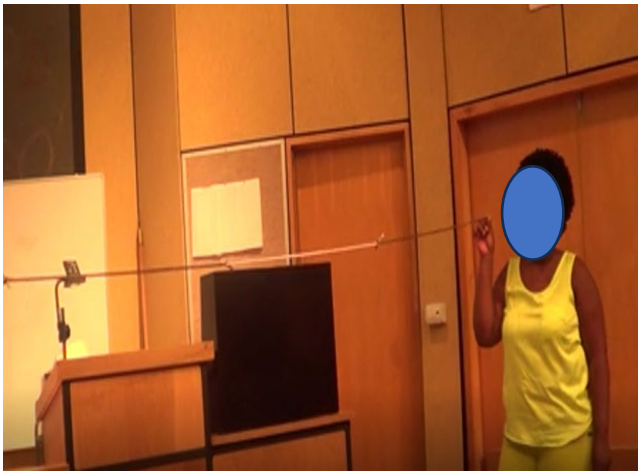


Figure 8.6 A student helping Dr Ellen with the demonstration of a gene using coloured strings tied together

During the demonstration, students were looking at the demonstration and some showed fascination as they were pointing at the strings and discussing with their peers. This evidenced that the demonstration captured the students' attention, and they were engaged during this MMO. Dr Ellen then said, "*Right, so this is DNA (demonstrating with a string) and the coloured section which is brown and white, and the different sections represent genes*." According to Sezer (2022), analogies help facilitate knowledge construction as they enable students to visualise abstract concepts in their minds based on familiar objects. This was no exception in Dr Ellen's case, as she used a string which is an everyday object that the students are familiar with to help them visually see and understand a "gene" as a section of DNA (represented by the brown and white coloured strings tied together). This became an area of interest during the VSRI because Dr Ellen had earlier alluded that she used research articles and the TSPCK framework to plan for her teaching. She was then asked if this approach stemmed from one of the articles that she read and why she decided to use it, Dr Ellen mentioned that:

"*No this is an original idea, I did not take it from anywhere, because I was really struggling to figure out how to show this relationship between genes and chromosomes… So, I went to our technician and requested a string. She gave me a ball of string. I took that ball and then I went and thought through how I was going to use it to show the relationship between DNA and chromosomes. And now I had to also think about how to show the relationship between the chromatin, DNA and chromatin then chromatin and chromosome. I was thinking about all these relationships, also gene and DNA, gene and genetic information all those things…now with these strings as DNA, how can I show that the gene is part of the DNA the section…*"

Dr Ellen's insights demonstrate the significance of a lecturer's familiarity with the areas of difficult concepts to teach and learn surrounding a topic (curricular saliency and component of TSPCK) as it seems to serve as a foundation for effective instructional planning. However, in addition to this

knowledge, it is equally vital for lecturers to harness their creativity in devising innovative and stimulating T&L strategies that are instrumental in the manifestation of MMOs that are aimed at facilitating student engagement and comprehension of challenging concepts.

During the demonstration, while using an analogy, Dr Ellen also asked the students a question, *"So, how would you define a gene?"* This was an open-ended question because it permitted the students to explain their understanding of the gene in various ways. The students provided various responses that included "*Could it be that DNA is made up of genes" "Can I take a guess? Uhmmm…they both carry information about a person. The DNA carries the makeup information, the small details like brown eyes something like that" "Will I be correct if I say DNA is a collection of genes?"* What was notable about the students' responses is that none of them were certain about their responses, but they were just eager to try. Thus, Sezer (2022) says that analogies are crucial for promoting active engagement because they encourage students to analyse scientific phenomena from their everyday perspectives based on what they can see. What was also noteworthy during this discussion was a question that was asked by one student "*Is there a reason why you used white, brown, white, brown so there are like two different types of genes? So, it's like mom dad, mom dad*?" This question posed by the student reinforces Sezer's (2022) argument that although analogies like demonstrations can be considered effective tools for enhancing conceptual understanding, they can sometimes lead to confusion and/or misconceptions among students. This viewpoint was also echoed by Dr Ellen during the VSRI when discussing the student's question, she mentioned that:

"…sometimes actually you are excited that you are explaining using some materials to try and explain something that is difficult but, in the process, you might actually be creating new misconceptions. And so I did say to the students, thank you for asking that question because in the following year, I planned better."

This incident highlights the importance of using demonstrations and/or analogies with caution as they can perpetuate misconceptions among students. This incident also stresses the significance of lecturers applying their creativity in their planning and teaching thus suggesting that the manifestation of 'stimulating' and/or 'effective' MMOs does not always occur by chance. Lecturers are also encouraged to actively engage their students in discussions to identify any possible misconceptions or confusion that may emerge from the use of these T&L strategies during MMOs.

MMOs resulting from a combination of visual representation lecturer explanation and a question [VR+LE+Q]

Table 8.2 above shows that the MMO type that involved visual representations, lecturer explanations, and questions was one of the most used by Dr Ellen as it had the second-highest frequency (12 out of 53 instances) at this level. The results suggest that Dr Ellen used visual representations to explain concepts and used questions to assess her students' comprehension of central concepts during MMOs.

An illustrative example of this MMO type occurred in lecturer 1 of episode 1 during an introduction to genetics. At the beginning of the lecture, Dr Ellen projected an image depicting genetic processes and products. She then prompted the students to discuss the image in pairs before sharing their ideas with the rest of the class. After a thorough discussion, Dr Ellen reinforced the concepts of genetics, inheritance, genetic material, and genetic information using a colour-coded slide depicted in Figure 8.7 below.

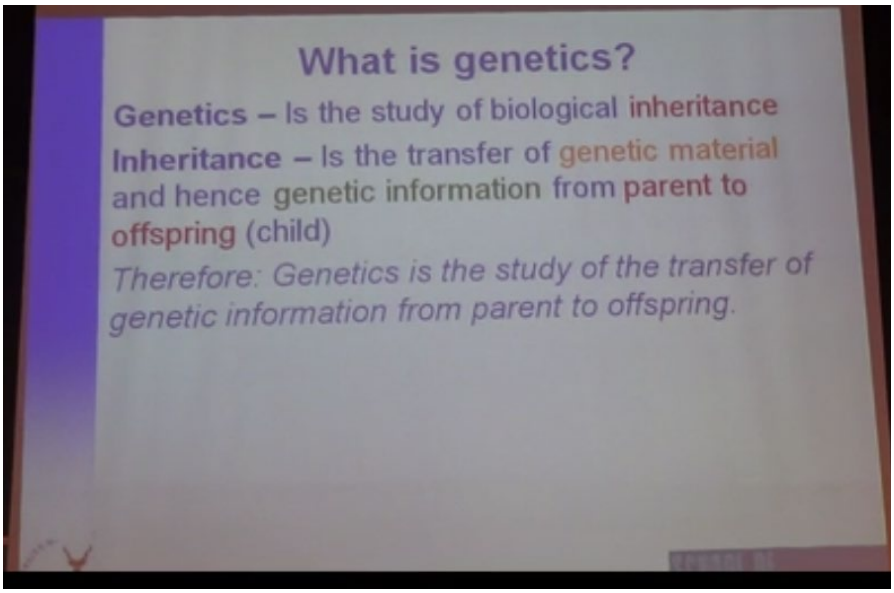


Figure 8.7 Colour-coded slide showing key terminologies

Although Dr Ellen was explaining these concepts without pointing at them, most students were seen looking at the slide, thus signalling engagement during the manifesting MMO. What was particularly interesting in this episode, was when Dr Ellen read the explanation of genetics as being the study of biological inheritance from the slide. As shown in Figure 8.5 above, the word 'inheritance' alongside other terms was bolded and according to her VSRI response she did this to, "*Emphasise the relationship between the concepts…. highlighting these concepts is part of the curricular saliency…"* This means that Dr Ellen was aware of the central concepts (Knowledge of curricular saliency) of the topic, and she bolded these terms to emphasise their importance to the students. Dr Ellen explained to them that they should note, "*I didn't simply say that genetics is the study of inheritance*". She then asked the students, "*Why is it important to specify biological inheritance?"* This was another open-ended question that required the students to justify their answers. However, without providing any waiting time for students to think about the question and formulate appropriate responses, Dr Ellen rephrased, and asked another open-ended question, *"Where else do you hear about inheritance?"*. One might argue that this might have been a missed opportunity that could have encouraged higher-order thinking amongst students. This is taking into consideration that open-ended questions are known to foster logical and critical thinking according to Bloom's taxonomy. Nonetheless, the open-ended question asked by Dr Ellen seem to have stimulated the students' thought processes about other contexts where the word

'inheritance' is used. One student responded by saying, "In reproduction". Dr Ellen provided the student with feedback saying, "*Okay in reproduction, that is correct*" Dr Ellen further probed by asking, "*but where else out there do you hear about inheritance?*" This shows that this question was open-ended in nature as it has more than one correct answer. Different students started murmuring indicating that although they were engaged during this MMO, but they were not necessarily certain about their answers. Dr Ellen picked one of the responses that was said by some of the students that were 'thinking out loud' and excitedly revoiced it by saying "*Yes, yes, in the will when someone dies and whatever possessions that person had will be shared and that is inheritance..."* This shows that Dr Ellen was somewhat aware of the dual meaning that the word "inheritance" has in both in the biological context and everyday social contexts. Ooyo (2017) refers to such terms as non-technical terms and argues that such terminology may pose challenges, especially for students whose first language is not English. These non-technical terms can hinder the students' understanding and may lead to undetected misconceptions that may be carried forward to the students' future learners. This incident, therefore, emphasises the need for biology lecturers to pay special attention to both technical and non-technical terminology when planning, especially given that as revealed by Dr Ellen during the VSRI, *"…terminology is one of the things that make genetics difficult to effectively teaching and learning of genetics…"* Therefore, it is crucial for lecturers to foster MMOs that help students master the key terminology (including both technical and non-technical terms) which are building blocks of the topic.

MMOs resulting from a combination of a question, feedback alongside gestures and/or actions [Q+FDCK+G/A]

The SE combination of feedback, gestures and/or actions alongside questions had the third highest frequency of 10 out of 53 at this level. This result reveals that Dr Ellen assessed or probed students' understanding using questions and provided feedback using gestures and/or actions. An example of this MMO type arose in episode 2 of lecture 2 when Dr Ellen introduced the process of meiosis and its importance during a whole class discussion. Dr Ellen asked the students "*Why is it important that there is genetic variation in an organism?"* this was again another open-ended question that required students to justify their responses thus again promoting higher-order thinking. One student responded by saying *"The variety makes us different, and we want to see variety in human beings.*" Dr Ellen agreed with the student's response and said "*Yes variety makes us different*" but Dr Ellen again posed the question whilst she folded her arms and walked closer to the students (an action and/or gesture), which signalled to the student that she was inviting more answers from them and was challenging them to think in depth about the question. Dr Ellen waited and looked at the students while there was murmuring which showed that they were involved, thinking about the question but uncertain about their responses. Another student raised their hand and mentioned:

"It has something to do with the fact that if there is like a disease or like if there is like a fault in the genes uhmm like it would keep coming back in a species uhmmm like do you know what I am saying??"

Despite the students' uncertainty in their response, Dr Ellen still acknowledged and reassured them by saying *"I know what you're saying (whilst smiling)"*, resulting in a positive emotional engagement that led the students to break into laughter. This interaction is evidence that both Dr Ellen and the students were emotionally and cognitively engaged during the manifesting MMO. Scott and Mortimer (2012) assert that such an emotional engagement among students can contribute to enjoyable and memorable learning experiences. Following this, Dr Ellen redirected the discussion and said, "*Let me ask a different question, have you ever sprayed cockroaches on a wall using Doom or Mortein Target*?" Although this question was closed-ended in nature, it was interesting because it was asked using an everyday activity that students are familiar with. The students all responded in unison and said "*yes*" whilst still laughing (indicating that they were still amused and engaged). Dr Ellen asked a series of questions that the students answered as shown in extract B below.

Extract B

Ss: Yess (All talk at once)
E: What happens?
S6: They die (Some Ss agree in support of this answer)
E: Do they all die?
Ss: No… (All answers at once)
E: Then what happens?
Ss: (All talking at once)
E: Some always survive why? (Points at a S who wants to respond)
S7: It is because different organisms in a species have different adaptations. So, the ones which are less adaptable tend to die and the ones which are adaptable tend to survive.

These results demonstrate that while questions, in general, can stimulate students' cognitive processes, open-ended questions, in particular, play a central role in fostering critical thinking among students during manifesting MMOs. Additionally, feedback provided during the learning process leads to extensive dialogic discussions, which frequently lead to significant and meaningful learning experiences (Çakır & Cengiz, 2016). Moreover, Scott and Mortimer (2012) argue that incorporating everyday phenomena that are familiar to students is crucial in establishing the relevance of concepts and facilitating the advancement of idea exchange during MMOs.

MMOs resulting from a combination of a question, feedback, and lecturer explanations [Q+ FDCK+LE]

The SE combination of a question, feedback, and a lecturer's explanation exhibited the fourth highest frequency, comprising 9 instances out of 53 at this level. This MMO type usually involved Dr Ellen typically engaging the students by posing a question, providing them with feedback, and subsequently elaborating on the underlying concepts. An example of such an MMO type occurred during episode 2

of lecture 2, where Dr Ellen initiated a whole class discussion on the process of meiosis and its significance. As depicted in **extract B** above, one of the questions posed by Dr Ellen to the students was about the survival of cockroaches after being sprayed with insecticide. Again, this was an open-ended question, which prompted the students to explain their reasoning. In response to this question, one student offered an explanation stating that "*It is because different organisms in a species have different adaptations. So, the ones which are less adaptable tend to die and the ones which are adaptable tend to survive."* Dr Ellen provided the students with feedback saying, *"Yes! Yes, that is the word I am looking for "adaptation"* Dr Ellen further explained:

So, if you spray cockroaches with Target Morten and Doom the first time a lot of them will die. But there will always be a few that will survive because they are different from the rest, and they were able to resist the insecticide that you sprayed at them. They will multiply and if you use the same insecticide that you used on them, many of them won't die because now they come from those that were resistant. So, it is the same with all living organisms, diversity and variation is so that if conditions in the environment change at least there will be some that will survive. So, it ensures the continuity of a species. So, as we are, if conditions change, some will have characteristics that are favourable to that particular environment and maybe the rest will perish. But there will be a few that will survive and those will continue the species. So, sexual reproduction is preferred for two reasons, 1. Continuity of species to multiply and 2. for adaptation as it brings about variation and therefore high chances of survival if conditions in the environment change and if those things are (approaches the students' direction-signalling engaging them) brought up by meiosis. It is through the process of meiosis that variation is introduced within a species and that's what we want to look at today...".

During Dr Ellen's explanation, some students seemed engaged as they were seen looking at her which signalled that they were listening while some were taking notes. However, despite Dr Ellen's comprehensive and detailed explanation, there were a few students who were observed engaging in discussions with their peers, indicating a potential disengagement from the lecture. This disengagement could be attributed to the prolonged duration of Dr Ellen's explanation. This observation aligns with Kampourakis et al.'s (2016) assertion that many students in higher education have limited attention spans, leading to disengagement during lengthy explanations, particularly when they are not supported by any visuals. This shortcoming can be explained by Dr Ellen stressing the two essential aspects of sexual reproduction organisms: (i) ensuring species continuity and multiplication and (ii) promoting adaptation for survival towards the end of the explanation without any visual support. Even so, Kampourakis et al. (2016) says that when lecturers emphasise certain concepts, they are ultimately focusing their students' attention on the most important concepts or the "big ideas" of the lecture or an explanation. Therefore, this finding suggests that while lecturer explanations play a crucial role in consolidating and organising students' ideas, they need to be either supported by visual representations or kept brief to maintain students' engagement during manifesting MMOs.

MMOs resulting from a combination of feedback, gestures and/or actions and writing /FDBK+G/A+WRTN/

Table 8.3 above revealed that in Dr Ellen's lectures, the combination of feedback, gestures and/or actions, and writing was seldom employed as it only accounted for 4 occurrences out of 53 instances at this level. This finding suggests that there was limited use of feedback provided to students through actions, and/ or gestures as well as through writing and/or drawing during Dr Ellen's lectures. An instance of this MMO type was evident once more during episode 1 of the lecture 1, during a whole-class discussion centred on the introduction of genetics. As earlier mentioned, Dr Ellen began this episode by projecting an image showing the processes and products of genetics as depicted in Figure 8.8 below.

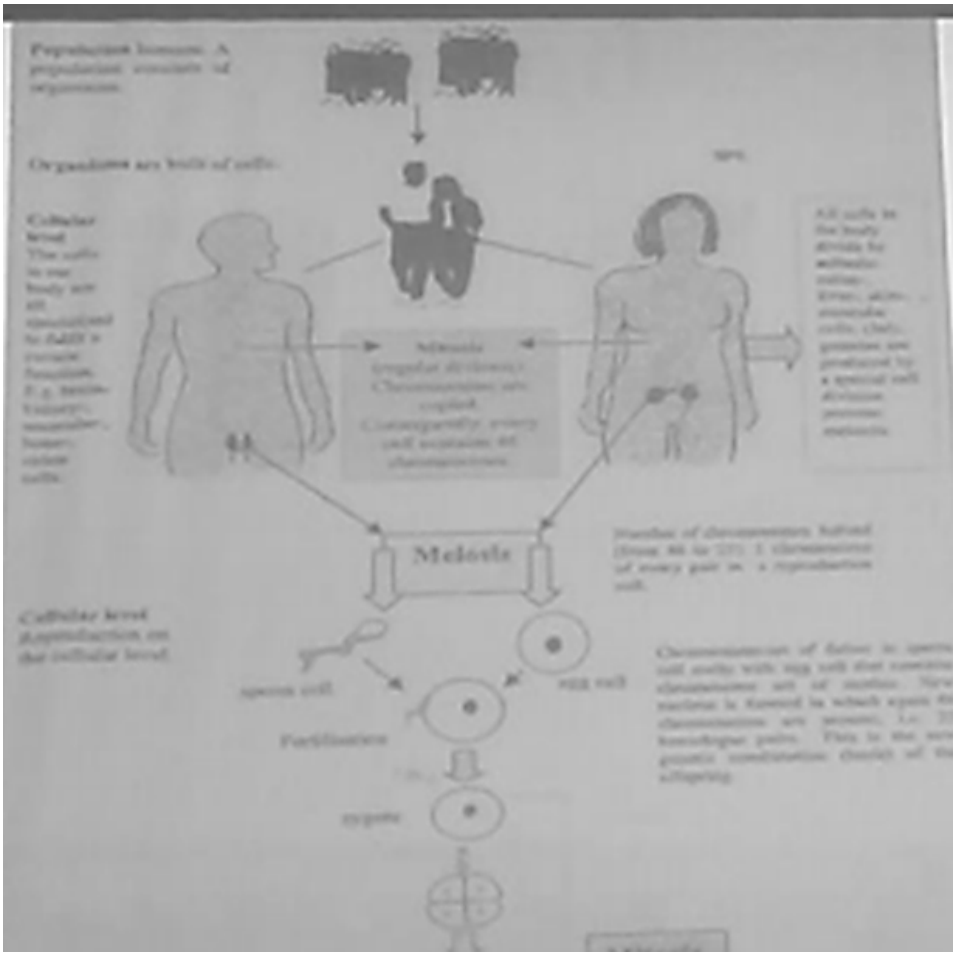


Figure 8.8 Products and processes of genetics and reproduction used to facilitate a whole class discussion

During the VSRIs this became another area of interest as to why Dr Ellen chose to start her lecture using this picture, she explained that:

"…*what informed me to choose that picture was the components of curricular saliency, where I wanted to make the link between reproduction to meiosis because students often see biology topics as being separate from each other…"*

Dr Ellen's response reveals that this MMO was deliberate and was a result of careful planning which was informed by her knowledge of curricular saliency related to the topic of genetics. This occurrence is further evidence that lecturers' knowledge of curricular saliency can assist in the manifestation of MMOs that are aimed at fostering cumulative learning. Such manifesting MMOs types can help the students see and understand the relationships that exist not only among various concepts but also across biology topics.

During the episode, Dr Ellen asked the students to say what they see in Figure 8.5. Again, this was an open-ended question given that different students interpret visuals differently thus resulting in different responses. One of the students mentioned "*The offspring is different from the parents"*. Although this was not necessarily visible in the black and white picture, therefore, making the response somewhat incorrect in this context. Dr Ellen still said *"okay"* while re-voicing the students' answers before turning towards the chalkboard and writing it there. During the VSRI, Dr Ellen was asked about her decision not to provide any corrective feedback when students were sharing their existing knowledge rather than describing what they specifically saw in the picture during this episode. In response, Dr Ellen explained that:

"Well, I wanted to gauge their thinking before making any comments. But when I did that, I was not expecting the answers that I got. I was actually thinking they would say exactly what is on the picture, that they see a female, they see a group of people, they see this and that... So, their answers also came as a surprise, but I did so because I wanted to get all their answers before engaging… I remember reflecting on it to say so what comes to students' minds it's not necessarily what is on the lectures' mind, as they were already interpreting which was a good thing because that interpretation helps you to see the knowledge gaps to see the misconceptions if they are any."

According to Dr Ellen's response, it is evident that the responses she encountered from some of the students were unexpected. However, she chose not to interrupt their thought processes and allowed them to fully exhaust all their ideas before providing consolidative feedback. This approach may explain the active engagement observed generally in her lectures and this episode. During this episode, while she was noting down the student's answer on the chalkboard, several other students had their hands raised, indicating their active participation and engagement in the discussion.

This episode illustrates that certain MMOs emerge spontaneously, as demonstrated by Dr Ellen's approach of refraining from providing immediate corrective feedback, which could have discouraged students from further participation. Instead, she seized this opportunity to evaluate whether any misconceptions existed among the students. Consequently, this occurrence highlights the significance of permitting students to openly express their thoughts during whole class discussions, without the provision of corrective feedback, particularly when the questions are based on their individual observations and perceptions. This approach is crucial, as providing corrective feedback may at times demotivate students from participating freely, as they may fear providing incorrect answers, especially in front of their peers during the learning process. Hence Mapplebeck and Dunlop (2021) argue that feedback is sometimes more detrimental than beneficial. This is because it can sometimes disturb critical thinking amongst students, as it positions them as mere "recipients of knowledge", while the teacher assumes the role of being the only provider of evaluative information thus dictating how students should behave and think which defeats the main purpose of learning.

MMOs resulting from a combination of lecturer explanations, gestures and/or actions and writing and/or drawing [LE+G/A+WRTN]

Table 8.2 above shows that the SE combination of lecturer explanations, gestures, and/or actions in conjunction with writing and/or drawing exhibited the lowest frequency of 2 out of 53 instances. Such an MMO manifested in episode 5, where there was a whole class discussion concerning the processes occurring in prophase during meiosis I. During this discussion, a student asked Dr Ellen "*Ma'am can you please explain the difference between a chromatid and a chromosome*", a commonly reported point of confusion among students when studying meiosis and mitosis (Thörne & Gericke, 2013). This incident further reveals the active engagement of the students in Dr Ellen's lecture, as they displayed self-directed learning by initiating discussions through asking questions. Dr Ellen clarified that:

"We refer to chromatids when we have these structures (demonstrate using the drawing on chalkboard). So, we can see this structure (pointing at the drawing showing chromatids on the chalkboard) we can't even see the two structures because of replication. So, this is a single-stranded chromosome but here because of the events and the behaviour of the chromosomes we are not able to see the two strands that were produced from replication, and we call them chromatids (pointing at the drawing showing chromatids on the chalkboard). But because they are still attached to each other, this whole thing is a chromosome (drawing an invisible circle around the chromosome) and now it is made up of two chromatids. (Comes towards the Ss and away from the chalkboard) Can we move on, I want us to look in detail at the next slide in greater detail. Just make sure that you are clear about what homologous means.

From the above, it is evident that Dr Ellen's approach to explaining chromatids and chromosomes was not abstract; instead, she consistently employed visual aids in the form of free-hand drawings on the chalkboard as shown in Figure 8.9 below, enabling the students to clearly see the distinctions between the two structures.

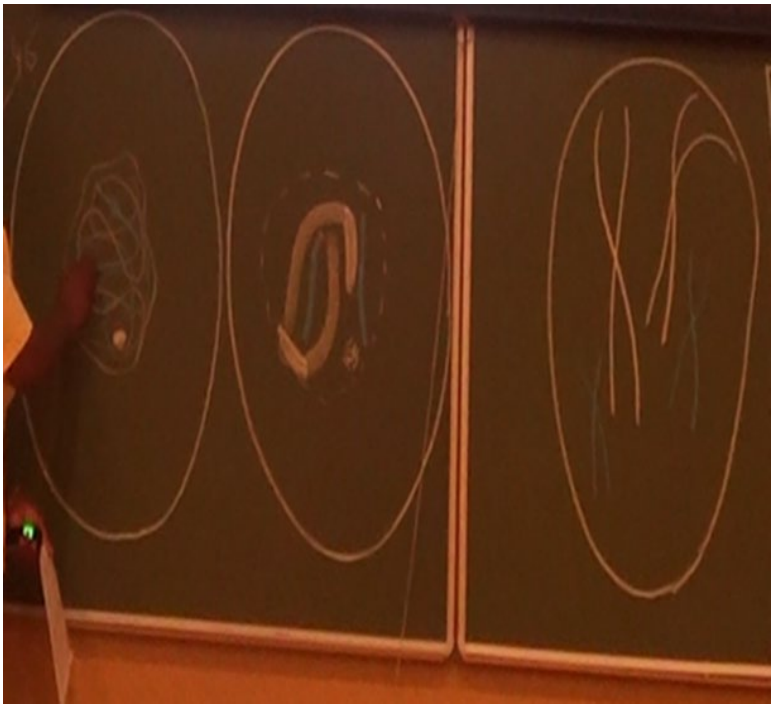


Figure 8.9 Dr Ellen explaining the difference between chromosomes and chromatids using a freehand-drawn diagram on the chalkboard

During the explanation, most students directed their attention towards the free-hand drawn diagram on the chalkboard, while some took notes, indicating their engagement during this manifesting MMO. This observation serves as evidence that incorporating visual stimuli during lengthy explanations significantly contributes to students' engagement during the learning of abstract constructs. It is essential to note that Dr Ellen did not inquire whether the student who asked the question comprehended the explanation, making it challenging to determine the effectiveness of the clarification provided for the two structures. Dr Ellen expressed her intention to move on to the next slide, specifically focusing on the concept of homologous chromosomes. Dr Ellen's actions to move on, may have made it difficult for the student to ask any follow-up questions, thus resulting in a somewhat missed opportunity. This

scenario contradicts the argument presented in Mapplebeck and Dunlop (2021) that highlights the importance of teachers assessing and addressing student confusion or misconceptions thoroughly to enhance their understanding of concepts and promote active participation in the learning processes. These results reveal that it is central for lecturers to pay attention and ensure that they thoroughly deal with the arising confusion and/or misconceptions during MMOs. These issues have the potential to impede future learning experiences, consequently adversely impacting their overall engagement during learning.

MMOs resulting from a combination of feedback, gestures and/or actions and visual representations [FDBK+ G/A+VR]

The combination of feedback alongside gestures and/or actions and visual representations had the lowest frequency of 2 out of 53. This SE combination involved Dr Ellen providing feedback based on gestures and/or actions and visual representations. An example of such an MMO type occurred in episode 9 of lecture 2 during a whole class discussion about metaphase. Dr Ellen commented and said *"Now there are changes that have occurred from number 3 to that one"* while she pointed (showing an action and/or gesture) at the image showing metaphase as demonstrated by Figure 8.10 below.

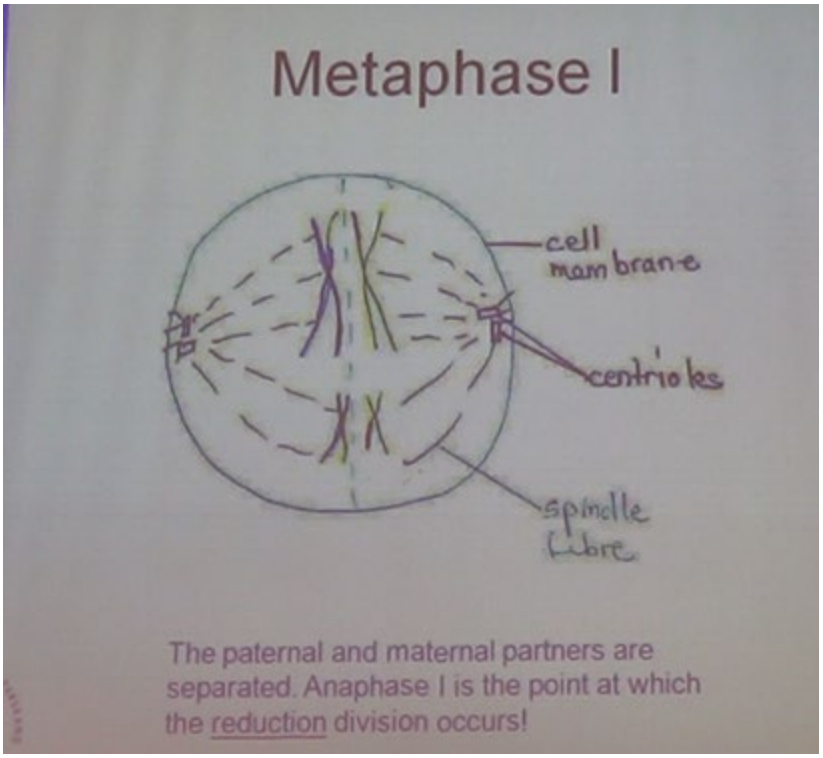


Figure 8.10 A colourful, labelled and annotated image of a cell in anaphase

Although Dr Ellen used a 2D representation that was colourful, labelled, and annotated, one student responded and said, "*The homologous chromosomes seem to have now lined up at the broken line there.*" Dr Ellen provided feedback and said "*Yes, the chromosomes have lined up at the centre and we*

call this broken line an equator of the spindle (Pointing at to the metaphase diagram on slide showing metaphase I)" Dr Ellen's response indicates her emphasis on correcting the student's use of appropriate terminology. However, it is worth noting that the student's misuse of terminology might have been influenced by the difficulty in reading the labels on the image, leading them to refer to the spindle fibres as "broken lines." Therefore, highlighting the significance of the lecturer ensuring that they use clearly labelled biological diagrams which can assist students in using appropriate genetic terminology during manifesting MMOs. This occurrence aligns with the assertion made by Gericke (2009) that clearly labelled biological structures are vital in the development of students' scientific literacy, thus enhancing their understanding of key concepts and/or content during MMOs.

8.2.3. Level 3 MMOs that resulted from the combination of four types of SEs

Table 8.3 above indicated that out of the total of sixteen MMO types that were observed in the two lectures, five resulted at this level with a combined frequency of 31 out of 128 instances **(making up a total of 24%)**. These results show that the number of MMO types that manifested at level 1 was the same as those that occurred at level 3. These findings suggest that there were generally a few MMO types that manifested in Dr Ellen's lecturers which accommodated students with either **three or four learning preferences.** The five MMOs consisted of the following:

1. Lecturer's explanation alongside a gesture and/or action, visual representation, and a question. [LE+G/A+VR+Q]
2. A question alongside feedback alongside a gesture and/or action and visual representation [Q +FDBK +G/A+VR]
3. A lecturer's explanation alongside a gesture and/or action, visual representation and an analogy [LE+G/A+VR+ANLG]
4. Feedback alongside a lecturer's explanation, gesture and/or action and a visual representation [FDCK+LE+G/A+VR]
5. Lecturer's explanations alongside writing and/or drawing, gesture and/or action and a question [LE+WRTN+G/A+Q]

In the subsequent sections, I explain in some detail with examples of how these seven MMO types manifested.

MMOs resulting from a combination of the lecturer's explanations alongside a gesture and/or action, visual representation, and a question. [LE+G/A+VR+Q]

Lecturer explanations alongside gestures and/or actions, visual representation and questions were among the highest frequency of 12 out of 32 at this level. This result indicates that Dr Ellen relied less on abstract verbal explanations and instead integrated visual aids to reinforce the content while actively involving the students through questions to assess their comprehension. For instance, a notable

occurrence of this MMO took place during episode 5 of lecture 1, where the whole class participated in a discussion following a paired activity centred around DNA, genes, chromosomes, and their interrelationships. During this interactive discussion, Dr Ellen used a colourful PowerPoint slide to visually illustrate genes at various levels, ranging from the micro to symbolic as represented by Figure 8.11 below.

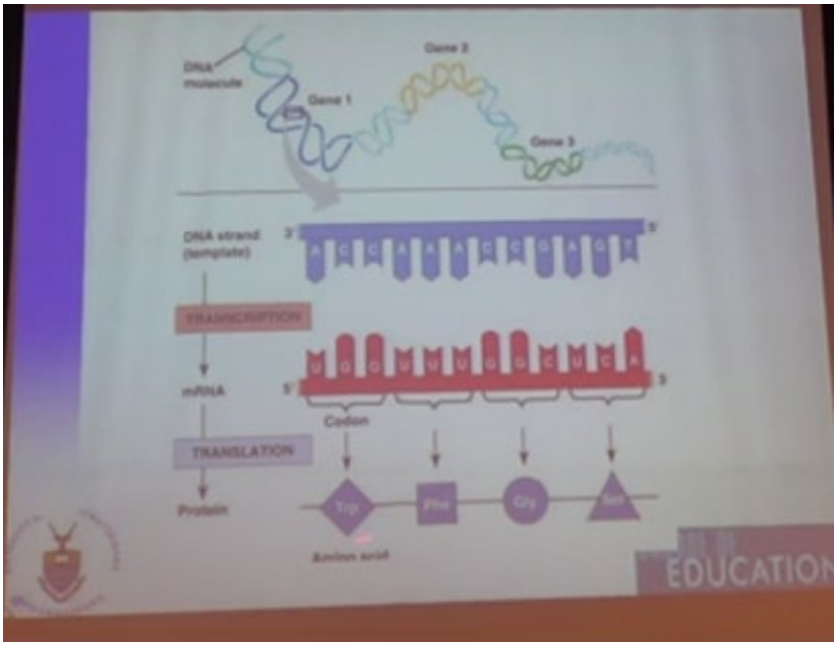


Figure 8.11 Image showing genes at different levels, ranging from the micro to symbolic level

Dr Ellen then used the colourful slide to explain that "…*genes are responsible for giving information for the production of a specific protein and so, this (pointing at the slide) is how it occurs. This is what you did with Mrs Moletsane. So, DNA is copied into RNA, we have three types of RNAs. Who can remember? Oh, they are already there. So, we have transcript RNA that is the one that copies the genetic information from DNA and then it is translated into a protein and then the protein form different features of an organism.*"

The colourful slide served as a reference point for Dr Ellen's explanation, where she emphasised that genes play a crucial role in providing information for the synthesis of specific proteins. She highlighted the process by which DNA is transcribed into RNA, with three types of RNAs involved in the process. Dr Ellen prompted the students to recall the different types of RNAs and again demonstrated her knowledge of curricular saliency by reminding the students that they had previously covered this topic with their previous lecturer. When asked why she made this connection during the VSRI, Dr Ellen noted that:

"*I like linking to the previous lectures and this always helps me to see which gaps or misconceptions they still have in their understanding. It also helps me identify their prior knowledge which can be linked to the new lecture that will kick-start the discussions."*

Dr Ellen's response suggests that it is important for lecturers to consistently connect new content with students' pre-existing knowledge when planning for MMOs. This approach serves a twofold purpose in the lecturers' MMO practises: (i) it helps identify and address any knowledge gaps or misconceptions that their students have; (ii) it fosters interactive and engaging learning experiences. Dr Ellen's response aligns with Ausubel's concept of meaningful learning, posited in 1963, which emphasises that new information is better retained and comprehended when it is built upon a foundation of existing knowledge. Scott and Mortimer (2012) also advocate for educational approaches that leverage on students' prior knowledge as a means of facilitating the development of new scientific knowledge during meaningful learning.

MMOs resulting from a combination of feedback, gestures and/or actions, visual representations and a question [FDBK+G/A+VR+Q]

The SE combination of feedback, gestures and/or actions, visual representations and a question had the second-highest frequency of 7 out of 32 at this level. This MMO involved Dr Ellen providing feedback based on visual representations and probing students further. Such an MMO manifested in episode 10 of lecture 1 where there was a whole class discussion about the cellular activities of anaphase I. One noteworthy moment occurred while Dr Ellen was explaining the process of independent assortment that results from the random pulling away of homologous chromosomes in anaphase, where a student asked about the randomness of assortment in dominant genes (signalling engagement during this MMO). Dr Ellen provided the student with feedback and said *Yes, the arrangement is random. For each pair, how it aligns is random. It can be as it is, or this one can come to this side and that one goes to that side* (Pointing at the metaphase diagram on slide)*."* To illustrate the concept further, Dr Ellen referred consistently to Figure 8.12 below which depicted how this random assortment occurs during anaphase and most students were seen looking at the slide while some were making their notes (indicating further engagement).

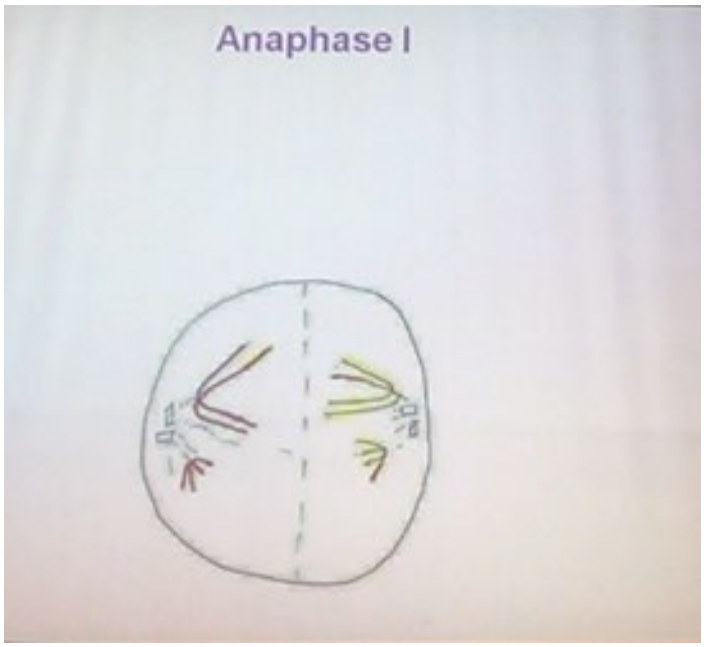


Figure 8.12 Cellular activities during anaphase I

The student responded by saying *"Ohh Okay that's why sometimes we look so alike yet so different"* The students' amusement and response sparked laughter from Dr Ellen as well as the other students which further evidence that there was emotional engagement. This instance shows that the way in which lecturers engage with their students' questions and provide feedback during MMOs is crucial in fostering understanding as it assists them in consolidating their own thinking about concepts.

MMOs resulting from a combination of a lecturer explanation alongside a gesture and/or action, visual representation and an analogy [LE+G/A+VR+ANLG]

The SE combination of an analogy alongside a gesture and/or action, a lecturer explanation and a question had the third highest frequency of 5 out of 32 at this level. An example of such an MMO manifested in episode 7 of lecture 1 during a whole class discussion about the organisation of DNA. During the episode, Dr Ellen explained to the students that:

"*And then now here (Points at them using the laser pointer) I am trying to show how DNA is organised now. This is a DNA molecule, and these are called histone protein, it is found in the nucleus because we need to organise the DNA into a chromosome. So, for DNA to form a ball that is a chromosome it needs histone to organise itself."*

Dr Ellen's explanations again placed emphasis on the DNA-chromosome relationship and how the histone proteins facilitate the whole process. While explaining, some of the students were seen listening to her while some were making notes which signals their involvement in this manifesting MMO. Dr

Ellen further displayed a picture of a DNA wrapping itself around the histone protein as depicted in Figure 8.13 below.

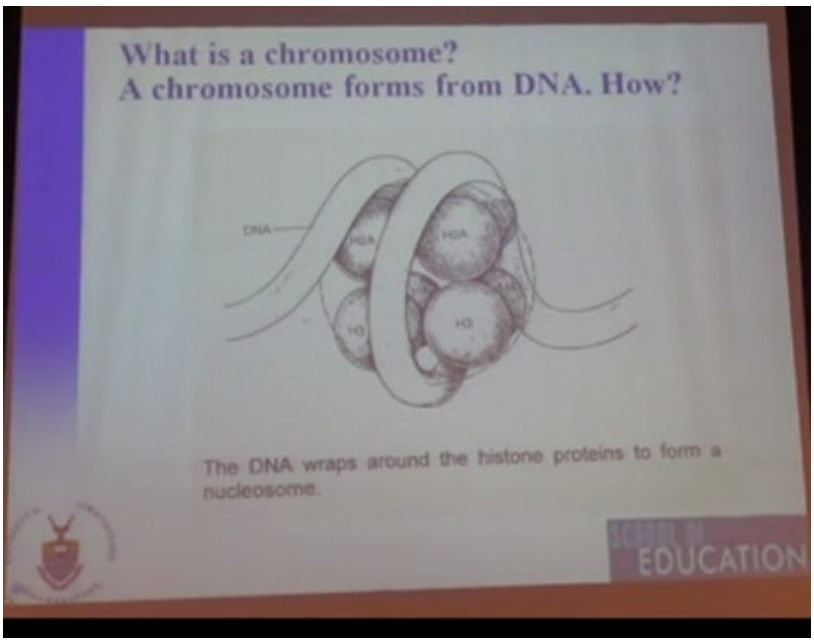


Figure 8.13 DNA wrapped around histone protein

Following Dr Ellen's scientific explanation, she proceeded to illustrate the concept to the students by demonstrating the process using a string wrapped around a cardboard roll, as depicted in Figure 8.14.

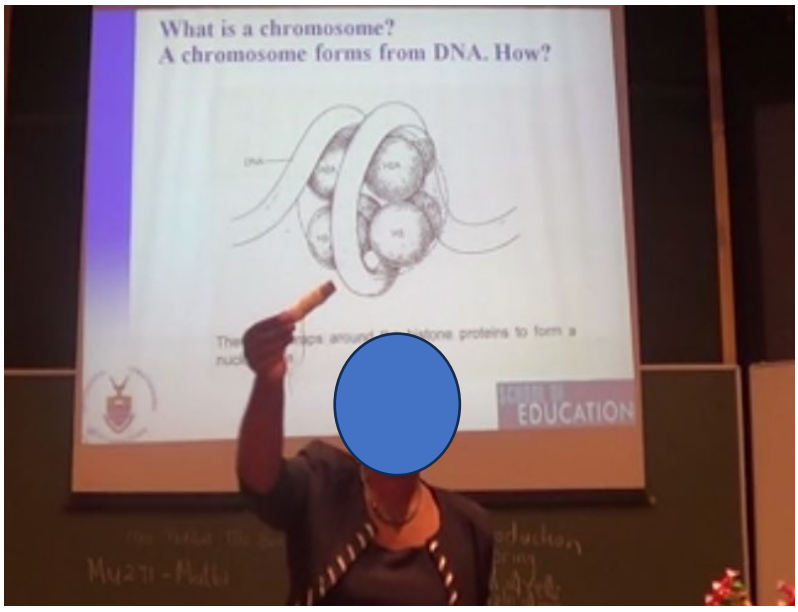


Figure 8.14 Dr Ellen demonstrating DNA wrapping around histone protein using a string rolled on a cardboard roll

Whilst demonstrating, Dr Ellen further explained how DNA organises itself into a chromosome using a demonstration and an analogy by saying that:

"…So, this carton roll (lifts the cardboard roll up to demonstrate to all the students) represents the histone proteins where the string represents the DNA and it is rolled on cardboard roll to form a compact structure called a chromosome, so that it can easily be transferred from one cell to the other during replication."

Dr Ellen's use of this everyday analogy and hands-on demonstration (gesture and/or actions) further resulted in the manifestation of a MMO that reinforced the comprehension of DNA's organisation into chromosomes among the students. This was evidenced by most students' focusing their attention to Dr Ellen during this MMO. As a result, this manifesting MMO further suggests that demonstrations play a vital role in supporting students' understanding of complex and abstract ideas, as it allows them to visually see how certain biological processes unfold in a tangible manner. Keri (2022) says that the human brain engages in an ongoing process of constructing analogies while learning, as means of establishing connections between familiar and unfamiliar concepts. When teachers or lecturers integrate analogies during teaching, they are effectively fostering the learning process. The reason behind this facilitation lies in demonstrations and analogies' ability to enable students to gain deeper insights into the scientific explanations of phenomena that are usually unobservable (Keri, 2022).

MMOs resulting from a combination of feedback alongside a lecturer explanation, gesture and/or action and visual representation FDCK+LE+G/A+VR

The SE combination of feedback alongside the lecturer's explanation, gestures and/or actions and visual representation had a relatively low occurrence, accounting for only 4 out of 32 instances at this level. This MMO type was observed during episode 5 of lecture 2 during a whole class discussion. In this episode, Dr Ellen requested the students to share the deliberations that emanated from their paired discussions concerning the cellular activities occurring from early to late prophase. One student was asked to respond about cell three which was a cell in late prophase. The student mentioned "*In cell 3 the chromosomes have paired up*". Dr Ellen provided feedback and further explained that:

"Yes, they have paired up! Looking at that (pointing at the cell showing late prophase) and those that have paired up are identical in size and shape and we refer to them as homologous chromosomes, and we call the process synapsis, and each pair is referred to as a bivalent. So, we can see there (pointing at the cell showing late prophase) is shortening and thickening and disintegration of the nucleolus and of the nuclear membrane. Then there is pairing of the homologous chromosomes to form bivalents."

Dr Ellen extended the student's response to support their understanding of the cellular processes that occur in a cell during the late stage of prophase. However, it may be argued that she missed an opportunity to instead retrieve this knowledge from the student(s) by probing them further about other observable differences that they could see in relation to the other two cells in earlier stages of prophase. After the explanation, Dr Ellen attempted to change the slide, but the students requested her not to as

they were still copying the notes, until she mentioned that "*You have this on Sakai, so you don't have to copy that…".* This incident support' the claim put forward by Cary and Branchaw (2017) that although explanations are important in instilling correct scientific understanding of the content among students, but it sometimes conditions students to over-rely on their instructors for knowledge. This episode, therefore, stresses the importance for lecturers to provide explanations after exhausting their student responses during discussions as means of developing their critical thinking abilities during MMOs.

MMOs resulting from a combination of a lecturer's explanation, alongside writing and/or drawing, gesture and/or action and a question [LE+WRTN+G/A+Q]

A lecturer's explanation, alongside writing and/or drawing, gesture and/or action and a question had the lowest frequency of 3 out of 32 at this level. An example of this MMO type manifested in episode 4 of lecture 2 during a pair discussion based on the processes of prophase. During the episode, Dr Ellen began by giving an overview of what is happening amongst the three different cells depicted in Figure 8.15 below.



Figure 8.15 Different cellular activities happening in early to late prophase

During the explanation, Dr Ellen mentioned the following:

"*And now we are moving on to meiosis. I have drawn the diagrams here (Points to the drawings of the cells in early to late prophase on the chalkboard) so initially, if you are looking at the process under the microscope you start off by seeing this (Points at the chromatin network drawn on the chalkboard) you can hardly see the chromosomes separate, but you'll see thread-like structures. Then we move on to these (Points at the short and thickened drawn chromosomes on the chalkboard) and then we move on to these. So, can you describe in your own words using the 3 diagrams what has happened? (Moves away from the chalkboard and walks towards the student. The Ss are quiet and continue to explain) So,*

although in that diagram shows the two strands, it is just a diagram for you to try and visualise what happens during replication. But you won't be seeing anything, the moment that you start seeing something is start off with a diagram like that (Points homologous chromosomes drawn on the chalkboard) and then you can see the process continuing to the next one to the next one. So, I want you to look at these three cells and describe the differences that you can see from one cell to another. Tell the person next to you."

The above passage reveals that Dr Ellen's explanation of the various cellular processes happening in the different cells which are at different stages of prophase was not exhaustive; instead, she only highlighted the key observations for each cell. This approach may have been deliberate to avoid influencing or pre-empting the students' thought processes, as her intention was to prompt them to participate in a pair activity, wherein they could collectively examine and differentiate between the cellular processes happening between the three cells. Subsequently, after instructing the students to engage in this pair activity, evident from the occurrence of murmuring among them, it became apparent that they were actively interacting with one another, signifying their engagement in the exercise. Throughout these discussions, Dr Ellen was observed interacting with students seated in the front row, as depicted in Figure 8.16 below.

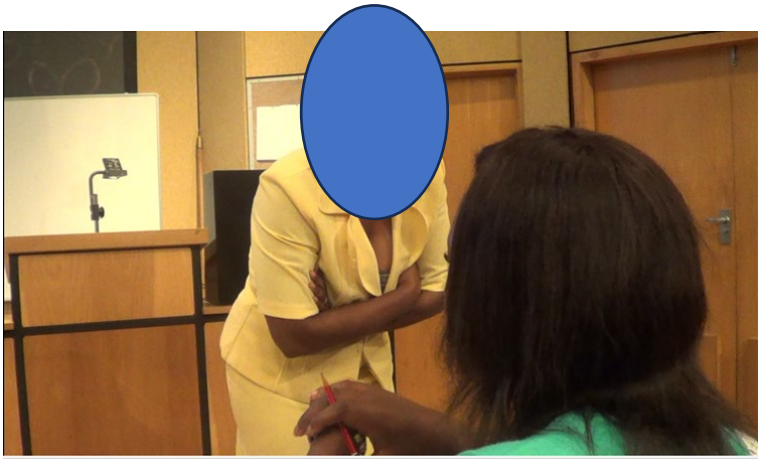


Figure 8.16 Dr Ellen engaging with some students seated in the front row during a pair activity

This became another segment of interest during the VSRI and Dr Ellen was asked about the purpose of monitoring her students during peer discussions and she said:

"*...making sure that they keep on task but of course they'll be others talking about something else so just me moving around to talk with a few is to ensure that they are on task they are discussing the task given, also to get feedback of their understanding of what you are assessing. If they understood what I was trying to teach them and just interacting with them and getting to know them this is the opportunity to get to do that.*"

Dr Ellen's response highlights that the monitoring of students during activities presents an opportunity for lectures to achieve multiple objectives, including (i) maintaining students' focus on the task at hand, (ii) evaluating the students' grasp of the subject matter, and (iii) fostering a deeper connection with them during manifesting MMOs. This occurrence aligns with Fischer (2013)'s claim that when lecturers move around their lecture venue during activities, this approach has the potential to humanise the learning experiences of students in higher learning contexts, as they get an opportunity to engage with their lecturers at a personal level. Nevertheless, Dr Ellen's remarks also show the drawbacks associated with the use of peer discussions in large lecture settings, which include the possibility of unproductive conversations among students. Consequently, this occurrence emphasises the importance for lecturers to actively monitor their students during tasks by moving around and being part of their students' discussions to ensure meaningful engagement during these MMOs that foster collaborative learning.

8.3. Discussion of the analysis and Conclusion(s)

This chapter presented an analysis of data from Dr Ellen, the fourth case. The analysis identified sixteen diverse types of MMOs, which manifested from combinations of all four social exchanges (SEs) which included, talk, visual representations, gestures and/or actions, and writing and/or drawing. These manifesting MMOs were classified into three levels of complexity, as outlined in Chapter 4. The majority of the manifesting MMOs in Dr Ellen's lectures were at Level 2, meaning that they were moderate in complexity and had the potential of accommodating students with two or three learning preferences. These MMOs frequently incorporated the SEs of lecturer explanations, gestures and/or actions, questions and feedback which engaged students in various ways. These MMOs often captured students' attention and helped bridge gaps in understanding by emphasising relationships between key concepts, such as DNA, genes, and chromosomes. Dr Ellen's use of analogies and demonstrations, such as string models to represent chromosomes, facilitated the visualisation of microscopic and sub-microscopic concepts thus maximising student engagement signalled by most of the students looking at the lecturer or demonstration. While effective, these MMOs sometimes posed challenges, such as inadvertently creating new misconceptions, which Dr Ellen addressed through adaptive feedback and explanations. These results reveal the need for lecturer to consider the types of demonstrations and analogies that they use as they can impact the manifestation of MMOs. Also, the findings also stress the importance of lecturer's having knowledge of the content that they teach, which is vital for addressing arising misconceptions during MMOs.

Level 1 MMOs accounted for the second-highest proportion of occurrences and typically combined two SEs, such as lecturer explanations, open and closed-ended questions or feedback. These MMOs predominantly engaged auditory learners, as they relied on dialogic exchanges that prompted students to recall prior knowledge or address misconceptions. For example, Dr Ellen frequently asked open-ended questions and provided corrective feedback, which encouraged students to engage in dialogic interactions and think critically about their responses. However, moments of disengagement

occasionally arose sometimes resulting in missed MMOs, particularly when visual representations or lengthy explanations were not used effectively, thus again highlighting how lecturers' use and planning of the various SEs matter in the manifestation of MMOs.

Level 3 MMOs, the most complex, integrated four SEs simultaneously, such as gestures and/or actions, lecturer explanations, visual representations, and questions. Although less frequent, these MMOs were particularly seen effective in engaging diverse learners and promoting deeper conceptual understanding. For instance, Dr Ellen used annotated visuals, color-coded slides, and interactive questioning to explain meiotic processes. By linking these processes to students' prior knowledge and everyday contexts, she also seemed to foster MMOs that engaged students in cumulative learning and reflection.

The analysis also emphasised Dr Ellen's responsiveness to students' needs, a key factor in the observed success of most of the manifesting MMOs in her lectures. Her knowledge of curricular saliency and common misconceptions and other components of TSPCK appeared to impact her planning of SEs and consequently the manifesting MMOs in her lectures. For example, her ability to clarify challenging concepts, such as the differences between chromatids and chromosomes, was enhanced by her use of meticulously planned lecturer explanations, analogies and visual representations. These results reveal that lecturers meticulous planning, levels of creativity, knowledge of misconceptions, knowledge of students and content influence the manifestation of MMOs. Despite these strengths, several challenges influenced the manifestation of MMOs in Dr Ellen's lectures such as unclear textbook diagrams, and close seating arrangements in the lecture venue and the complexity of genetic terminology posed barriers during lectures.

Additionally, Dr Ellen's use of humour and teaching philosophy grounded in constructivism fostered a positive learning environment which might explain the high levels of students' engagements observed during the lectures. The positive learning environment again appeared to foster the manifestation of MMOs that encouraged active participation during discussions. Therefore, the analysis cements the importance of lectures' personalities and the role of a constructivism as a teaching philosophy in the manifestation of MMOs.

In summary, this chapter has provided a detailed account of how MMOs manifested in Dr Ellen's biology lectures. It highlighted the critical role of the use of diverse SEs, the importance careful planning, creativity, selecting and tailoring suitable teaching strategies to student needs, knowledge of the content, students, context, misconceptions and curricular saliency in the manifestation of MMOs and possibly addressing challenges such as misconceptions and disengagement during lectures.

Chapter 9

Pulling it together: A cross-case analysis of the MMOs manifesting in the four biology lecturers' teaching

9.0. Introduction

The four preceding chapters introduced and expounded on the four case studies of Drs Chris (cell biology), Molly (mitosis and animal tissues), Moses (osmoregulation and excretion), and Ellen (genetics and meiosis). These four previous chapters also documented the various MMOs that manifested in the lectures. In this study, a combination of any two or more SEs, where one of the SE is talk, was considered as an MMO. The different SE combinations resulted in different types of MMOs as previously explained in Chapter 4. Therefore, this chapter seeks to employ a cross-case approach to further examine any significant parallels and/or distinctions that exist in the already documented MMO types that manifested across the lectures. Borman et al. (2012) explain a cross-case analysis as an approach that permits the researcher to look at two or more cases to see how they are similar or different from each other. This comparative analysis approach was deliberately used to gain insights into any significant implications associated with the use of the SEs and manifesting MMO types that appeared across the four lectures. To conclude this chapter, a synthesis of insights was offered in response to the three research questions proposed in this study.

9.1. The nature of the MMO types manifesting in the lectures and their implications

The case-by-case analysis revealed that Drs Ellen, Chris, and Moses all used four SEs which were talk, visual representations, gestures and/ or actions, and writing and drawing which all led to the manifestation of MMOs in their biology lectures. Dr Molly on the other hand only used three out of the four SEs which also promoted the manifestation of MMOs in her lectures, except for writing and/or drawing. The lecturers' use of these SE combinations resulted in the manifestation of thirty-one distinct types of MMOs as represented in Table 9.1 below. These MMO types were subsequently categorised into three levels. As previously explained, MMO types at level 1 resulted from the combination of any two SEs, while level 2 MMO types resulted from any three SEs and level 3 MMO types resulted from all four SEs interacting with one another. These findings are consistent with Vygotsky's (1978) sociocultural theory, which positions learning as mediated through social interaction and semiotic tools.

Table 9.1 below provides an overview of the occurrences of the different MMO types that manifested across the lectures. To help the reader decode the information tabulated below, it is important to note that the cross (**X**) signifies the absence of an MMO type in that lecture the grey highlight signifies the absence of the MMO types across the lectures.

Table 9.1 Summary of the manifesting MMO types across the lectures

Level 1 MMO types	Chris	Molly	Moses	Ellen	Level 2 MMO types	Chris	Molly	Moses	Ellen	Level 3 MMO types	Chris	Molly	Moses	Ellen
1.1. [LE+Q]	**12**	**23**	**8**	**13**	2.1. [GA+VR+LE]	23	17	10	12	3.1. [LE+ G/A+VR+[Q]	5	6	X	12
1.2.[VR+Q]	**20**	**22**	**10**	X	2.2. [Q+G/A+VR]	13	13	8	X	**3.2. [** FDBK + LE+ G/A + VR]	5	4	X	4
1.3[G/A+Q]	**14**	**21**	**8**	X	2.3**. [**LE+ANLG+Q]	X	6	X	X	3.3. [LE+WRTN+G/A+VR]	2	X	4	X
1.4.[FDBK +Q]	**11**	**15**	X	**14**	2.4. [FDBK+ G/A+VR]	**13**	X	**3**	**2**	3.4. [LE+WRTN+G/A+Q]	X	X	**3**	**3**
1.5[G/A+ FDBK]	X	**13**	X	X	**2.5.** [FDBK+LE+WRTN	X	X	8	X	3.5. LE+G/A+VR+ANLG	X	X	X	5
1.6[LE+G/A]	**9**	**12**	**4**	**7**	2.6. [LE+ WRTN+ Q]	X	X	**7**	X	3.6. [Q+ FDBK+G/A+VR]	X	X	**2**	**7**
1.7.[LE+ FDBK]	X	**10**	X	X	**2.7. [**ANLG+G/A+Q]	X	X	X	14					
1.8.[LE+ VR]	X	**6**	X	**4**	2.8. [Q+ FDCK+G/A]	X	X	X	**10**					
1.9.[MNM+Q]	X	**2**	X	X	2.9. Q+FDCK+LE	X	X	X	9					
1.10.[ANL+G/A]	**2**	X	X	X	2.10. [FDBK+G/A+WRTN	X	X	X	4					
1.11.[LE+WRTN]	X	X	**13**	X	2.11. [LE+G/A+WRTN	X	X	X	2					
1.12 [FDBK+WRTN]	X	X	**11**	X		X	X	X	X					
1.13. [WRTN+Q]	X	X	**9**	X		X	X	X	X					
1.14. FDCK+ANLG	X	X	X	**4**		X	X	X	X					
Total Frequency per lectures	**68**	**124**	**63**	**44**		**49**	**36**	**36**	**53**		**12**	**10**	**9**	**31**
Total Frequency across the lectures	**299 out of 524 (57%)**					**174 out of 524 (33%)**					**51 out of 524 (10%)**			

Keys: *(X) signifies the absence of an MMO type in a lecture* *signified the absence of the MMO types across the lectures.*

Table 9.1 above provides insights there was a total of 524 of MMO instances recorded across all levels (299+174+51) that manifested in the different observed lectures. Table 9.1 further reveals that, at level 1, there was a total of fourteen distinct MMO types, displaying a cumulative frequency of 299 out of 524 (constituting 57%). At level 2, there was a slight decrease in the manifestation of MMO types, with a total of eleven MMO types with a total frequency of 174 out of 524 (comprising 33%). At level 3, a substantial decline in the SE combination was evident, as only six MMO types manifested, accounting for a total frequency of 51 out of 524 (making up 10%). These findings suggest that generally the MMO types manifesting across the different lectures ranged at level 1 and were basic in nature, resulting from the combination of only two SEs, thus, mainly accommodating students of either one or two learning preferences.

A close examination of Table 9.1 presented above, revealed that although Drs Chris, Molly and Moses demonstrated a range of MMO types between levels 1 and 2, Dr Molly's MMO types appeared comparatively basic in nature than those of the other two lectures. This observation is confirmed by the highest occurrence of 9 SE combinations and the highest frequency, reaching 124 at level 1, in her lectures surpassing the frequencies observed in other lectures. These results may be justified by the brevity of her lectures caused by the disruptions at SAX and technological issues as explained in Chapter 6. These results reveal that time constraints and technology-related issues can negatively impact the manifestation of 'rich' MMOs.

On the contrary, Dr Ellen's MMO types extended across levels 2 and 3, presenting the highest SE combinations at both levels (8 combinations at level 2 and 15 at level 3). Additionally, the MMO types manifesting in Dr Ellen's lectures also exhibited the highest frequencies at both levels compared to the other lectures. These results imply that Dr Ellen's manifesting MMO types ranged between average and complex, thus mostly accommodating students with three or more learning preferences. These results confirm that Dr Ellen's lectures displayed an array of complex MMO types that provided opportunities for students of different learning preferences to engage with the genetics concepts in various meaningful ways. These results were of particular interest, considering the assertion made by Nyamupangedengu (2015) that genetics is arguably one of the most challenging topics within the field of biology. This assertion gains additional support from a study conducted by Fauzi and Fariantika in 2018, titled "*Courses perceived as difficult by undergraduate students majoring in biology*" which also revealed that most undergraduate students who participated in the study viewed genetics to be a difficult module, because of the abstract and confusing terminology. This disparity in the 'richness' of the manifesting MMOs may be again attributed to Dr Ellen's creative use of instructional materials as well as her adoption of TSPCK in her planning, which is a pedagogical framework recognised for its ability to help teachers transform complex content into accessible chunks that students can easily understand. As revealed in Chapters 2, the TSPCK model comprises five categories which involve: (i) learners' prior knowledge including misconceptions, (ii) curricular saliency, (iii) what makes the topic easy or difficult

to understand, (iv) representations including powerful examples and analogies, and (v) conceptual teaching strategies (Mavhunga & Rollnick, 2013, p. 834.), which all seemed to bring about the 'sophistication" or 'richness' of the MMOs that manifested in her lectures as exemplified in the below subsections.

9.1.1. The importance of learners' prior knowledge and their misconceptions in the manifestation of 'rich' MMOs

Drs Molly and Ellen encountered a spontaneous manifesting MMO which involved a common misconception raised by the students. One common misconception that both lecturers encountered was related to the difference between chromosomes and chromatids, which Thörne and Gericke (2013) argue is one of the widely held misconceptions related to genetics. Dr Ellen proficiently addressed the misconception, revealing her awareness of the misconception thus using the SEs involving LE+WRTN+G/A+VR to engage her student with the misconception. This stands in contrast to Dr Molly, who encountered greater difficulty in addressing this misconception while using a similar complex MMO type that involved [LE+ G/A+VR+[Q]. The difficulty experienced by Dr Molly may have stemmed from her apparent lack of awareness of this existing misconception related to the topic and its source of origin, unlike Dr Ellen. This became evident during Lecturer 2 when Dr Molly asked her students' where their knowledge of chromatids and chromosomes came from. Some students informed her that their understanding came from their "*...high school..." and "...textbooks...*". This occurrence further supports Sanders and Makotsa's (2016) argument that biology textbooks are one of the main sources of misconceptions that can cause conceptual challenges during learning. Coley and Tanner (2015) advocate for teachers to be familiar with textbook content and potential misconceptions. Such awareness allows teachers to serve as facilitators and mediators of knowledge, ensuring students develop an accurate understanding of biology concepts. This finding is particularly critical for teacher training programs because it advocates that lecturers must sensitise or concientise future educators to these potential misconceptions. As revealed from the analysis above, failure to address these gaps can impede meaningful learning, as seen in Dr Molly's lecture, thus further emphasising the importance of lecturers in engaging students in MMOs that are aimed at addressing and dispelling misconceptions.

These insights from the two lecturers (Drs Molly and Ellen) revealed that the 'richness' or 'sophistication' of MMOs does not only rests on the use of complex MMOs. Dr Ellen's instance revealed that the lecturer's awareness or knowledge of the type of misconceptions (a component of TSPCK) that exist in their topic also helped in deliberately planning SEs that led to the manifestation of 'rich' MMOs. Such richness was characterised by pedagogical depth which is the ability to surface and address misconceptions, link new content to students' prior knowledge, and foster higher-order thinking. This awareness also allowed Dr Ellen to adapt and respond effectively to emerging student needs during spontaneously occurring MMOs.

9.1.2. The importance of what makes the topic easy or difficult, students' prior knowledge and curricular saliency in the manifestation of 'rich' MMOs

It can be seen Dr Ellen also fostered the manifestation of 'rich' MMO types that involved the use of [LE+ G/A+VR+[Q] and [FDBK + LE+ G/A + VR] which emerged in lecture 1 of the episode as previously explained in Chapter 8. During lecture 1, Dr Ellen explained to the students that *"…terminology is one of the things that make genetics difficult to effectively teaching and learning of genetics look at the number of concepts already in just that one slide…"* This statement reflected Dr Ellen's knowledge of what makes the topic of genetics easy or difficult [another aspect of TSPCK]. To address this difficulty associated with the terminology of genetics, Dr Ellen again used a repertoire of colour-coded visuals (as exemplified by figures presented in Chapter 8) which reflected her knowledge of curricular saliency (another aspect of TSPCK).

Dr Ellen often used these colour-coded visuals as an initial stimulus to initiate a discussion regarding the students' prior knowledge of various concepts such as 'inheritance', demonstrating her awareness of the potential dual interpretations associated with the term and the potential challenges it might pose for multilingual students in comprehending its significance and meaning in the context of biology. After interacting with the students' responses about their understanding of the concept and providing feedback, Dr Ellen proceeded to explain the biological concept of inheritance using the visual representation, which engaged students to listen, visualise, and prompting some to write notes. This particular instance revealed that the 'richness' and sophistication of the manifesting MMO stemmed from Dr Ellens' deliberate design of the colour-coded slides and planning of explanations and questions (all SEs) which was informed by her knowledge of curricular saliency and what makes the topic easy or difficult to teach. During the VSRIs, Dr Ellen explained that she deliberately used these colour-coded slides because:

"*I wanted to help the students to see the important terminology…. for them to make links of the concepts and easily make sense of these concepts by discussing these with their peers…*".

Dr Ellen's response reveals that she wanted to foster a cumulative understanding of concepts as well as help her students see the intricate relationships that exist among concepts. These findings further support the significance of lecturers possessing a comprehensive and in-depth understanding of their topics. This can assist them in identifying the difficulties that students may encounter during their topics. They are then able to intentionally plan SEs that can promote the manifestation of 'rich' MMOs aimed at supporting their students in navigating and gaining mastery of the difficult terminologies as well as developing an understanding of their relationships during learning.

9.1.3. The importance of the use of powerful examples, analogies and conceptual teaching strategies in the manifestation of 'rich' MMOs

The analysis revealed that all lecturers used analogies and examples to promote the manifestation of MMOs in their lectures, which were crucial in resolving confusion and misunderstandings among

students during lectures. However, Drs Chris, Molly, and Moses used analogies which only led to MMOs ranging between levels 1 and 2, as indicated in Table 9.3 (see Chapters 5, 6 and 7). In contrast, Dr Ellen's use of analogies resulted in a complex MMOs that could be categorised at level 3. Such a manifestation of a MMO was exampled when Dr Ellen made use of the following SEs which involved lecturer explanations, gestures and/or actions, visual representations, and analogies **[LE+G/A+VR+ANLG]** and **[LE+G/A+ ANLG +Q].** The manifestation of these MMOs was important in developing a conceptual understanding of the structures and relationships between genes, DNA, and chromosomes among her students. As outlined in Chapter 8, to bring about this conceptual change, Dr Ellen used household materials to facilitate student comprehension, specifically employing strings to represent DNA (unwound string) and chromosomes (wound string), effectively illustrating the structural differences between the two. These findings underscore the importance of analogies in manifesting MMOs during biology lectures, particularly in resolving confusion. The 'richness' of such MMOs is significantly enhanced by the lecturer's awareness of the difficulties inherent in the topic and their careful planning of SEs. Therefore, these results suggest that the manifestation of 'rich' MMOs, involving analogies and examples that lead to conceptual change among students, is contingent upon the lecturer's creativity, content expertise informed by research, and deliberate preparation.

Dr Ellen, in the VSRI, when asked about how she came up with all these different teaching strategies, one of the key things highlighted was "*...planning all these activities takes a lot of time, although they are effective in engaging students, but they are not always easy to do."* Dr Ellen's response alludes to that although using a repertoire of T&L strategies is ideal for fostering meaningful learning, it is not an easy task to achieve due to time constraints. This response may potentially explain the general decrease in the MMO types as the levels increases, especially taking into consideration that lecturers have multiple responsibilities that involve teaching modules at specified periods, other administrative duties (recording students' marks), and conducting research to mention a few (Fischer, 2013).

9.2. The relationship between the manifesting MMO types and forms of student engagement

Table 9.1 illustrates the diverse MMOs that emerged across the lectures, stemming from varying combinations of SEs, which subsequently influenced different forms of student engagement (a concept detailed in Chapters 2 and 4). Table 9.2 below further proves an overview of how these distinct MMO types, documented across the lectures, gave rise to different forms of student engagement. This section was important in providing insights to sub-research question 2, which was interesting in understanding the various forms of student engagements that were elicited by the manifested MMOs in the biology lectures.

Table 9.2 Summary of the MMO types and various forms of student engagement that manifested across the lectures

Level 1		Level 2		Level 3	
MMO types	Types of engagement manifesting, with "few" students in the video are seen:	MMO types	Types of engagement manifesting "More than half" students in the video are seen:	MMO types	Types of engagement manifesting "Most and/or All" students in the video are seen:
1.[LE+Q]	*Looking at the lecturer*/ raising their hands, and/or asking questions discussing/ writing notes and/or making drawings	1. [GA+VR+LE]	*Looking at the demonstration*/screen/ *lecturer*/writing notes and/or making drawings	1. [LE+ G/A+VR+[Q]	*Looking at the lecturer*/*demonstration*/screen/raising hands, answering and/or asking questions/ discussing/writing notes and/or making drawings
2.[VR+Q]	Looking at the screen/ raising their hands, and/or asking questions/discussing/writing notes and/or making drawings	2. [Q+G/A+VR]	Raising their hands, answering and/or asking questions/discussing/ *looking at the demonstration*/ screen/ writing notes and/or making drawings	2. [FDBK + LE+ G/A + VR]	*Looking at the lecturer*/*demonstration*/ screen/writing notes and/or making drawings
3.[G/A+Q]	*Looking at the demonstration*/ raising their hands, and/or asking questions / discussing/writing notes and/or making drawings	.3. [LE+ANLG+Q]	*Looking at the lecturer*/ raising their hands, answering and/or asking questions/discussing/ writing notes and/or making drawings	3. [LE+WRTN+G/A+VR]	*Looking at the lecturer*/ board/*demonstration*/screen/writing notes and/or making drawings
4.[FDBK +Q]	*Looking at the lecturer*/ raising their hands, and/or asking questions /discussing/ writing notes and/or making drawings	4. [FDBK+ G/A+VR]	*Looking at the lecturer*/ *demonstration*/ screen/ writing notes and/or making drawings	4. [LE+WRTN+G/A+Q]	*Looking at the lecturer*/ board/*demonstration* /screen/ raising their hands, and/or asking questions/discussing/ writing notes and/or making drawings
5.[G/A+ FDBK]	*Looking at the demonstration*/ *lecturer*/writing notes and/or making drawings	5. [FDBK+LE+ WRTN]	*Looking at the lecturer*, board/writing notes and/or making drawings	.5. LE+G/A+VR+ANLG	*Looking at the lecturer*/*demonstration*/ screen/ writing notes and/or making drawings
6.[LE+G/A]	*Looking at the lecturer*/*demonstration*/writing notes and/or making drawings	6. [LE+ WRTN+ Q]	*Looking at the lecturer*/board /raising their hands, answering and/or asking questions/ discussing/writing notes and/or making drawings	6. Q+ FDBK+G/A+VR	Raising their hands and/or asking questions/discussing/ *looking at the lecturer*/*demonstration*/screen/ writing notes and/or making drawings
7.[LE+ FDBK]	*Looking at the lecturer*/writing notes and/or making drawings	7. ANLG+G/A+Q	*Looking at the lecturer*/*demonstration*/raising their hands answering and/or asking questions /dissing/ writing notes and/or making drawings		
8.[LE+ VR]	*Looking at the lecturer*/screen/writing notes and/or making drawings	8. Q+ FDBK+G/A	Raising their hands answering and/or asking questions / discussing/*looking at the lecturer* /*demonstration*/writing notes and/or making drawings		
9.[MNM+Q]	*Looking at the lecturer*/ raising their hands, and/or asking questions /discussing/writing notes and/or making drawings	9.Q+FDBK+ LE	Raising their hands, answering and/or asking questions/discussing/ *looking at the lecturer*/writing notes and/or making drawings		
10. [ANL+G/A]	*Looking at the lecturer*/*demonstration*/writing notes and/or making drawings	10.FDBK+G/A+WRTN	*Looking at the lecturer*/*demonstration*/board/ writing notes and/or making drawings		
11.[LE+WRTN]	*Looking at the lecturer*/board/writing notes and/or making drawings	11. LE+G/A+WRTN	*Looking at the lecturer*/*demonstration*/board/ writing notes and/or making drawings		

12.[FDBK+ WRTN]	***Looking at the lecturer*/board/writing notes and/or making drawings**				
13. [WRTN+Q]	**Looking at the board/ raising their hands, and/or asking questions /discussing/writing notes and/or making drawings/discussion**				
14. [FDCK+ANLG	***Looking at the lecturer*/writing notes and/or making drawings**				

It can be seen from Table 9.2 above, that these different SEs employed by lecturers led to the manifestations of various MMO types and forms of engagement in the lectures. These results provided evidence that the use of SEs in various combinations is crucial in the manifestation of MMOs aimed at engaging students of different learning preference in biology lectures. Notably, some SE combinations resulted in the manifestation of MMO types across different levels that exhibited identical patterns of student engagement. For instance, at level 1, it was observed that the MMO types [G/A+ FDBK], [LE+G/A], [ANL+G/A]) displayed the same pattern of student engagement which involved students in **looking at the demonstration/looking at the lecturer** (either explaining, providing feedback or using an analogy)/**writing note or making drawings**. It is important to mention that note-taking seemed to be a continuous activity in all the lectures despite the type of MMO manifesting, suggesting that the biology students in the lectures were inclined towards formulating meanings through written modes of learning and could actively engage with any MMO type. These results support Fischer (2013)'s assertions that notetaking is a result of active listening which is used particularly by adult students to organise and refine their thoughts during meaningful learning.

To systematise these emerging patterns showing the various forms of student engagement, a comprehensive mapping was conducted of all thirty-one observed MMO types that manifested across the lectures. This systematic approach resulted in the identification of fourteen distinct patterns of student engagements that manifested from the total of 31 MMO types that emerged across the lectures. Out of fourteen patterns, six MMO types displayed distinct patterns of engagement that did not align with any of the identified groups and served unique functions, as outlined in Table 9.3 below.

Table 9.3. Summary of Student engagement patterns across the three MMO levels

Group	MMO types	Manifesting forms of student engagement
1	• [LE+Q] • [MNM+Q] • Q+FDCK+LE]	Looking at the lecturer/ raising their hands, and/or asking questions/discussing/writing notes and/or making drawings
2	• [VR+Q] • [FDBK +Q] • [LE+ANLG+Q]	Looking at the screen/ raising their hands, and/or asking questions /discussing/ writing notes and/or making drawings
3	• [G/A+ FDBK] • [LE+G/A] • [ANL+G/A]	Looking at the lecturer/demonstration/ writing notes and/or making drawings
4	• [LE+WRTN] [FDBK+WRTN] • [FDBK+ G/A+VR]	Looking at the lecturer/board/writing notes and/or making drawings
5	• FDBK+G/A+WRTN] • [LE+G/A+WRTN] • [LE+WRTN+G/A+VR] • [LE+G/A+VR+ANLG]	Looking at the lecturer/writing notes and/or making drawings
6	• [Q+G/A+VR] • [LE+WRTN+G/A+Q] • [Q+ FDBK+G/A+VR]	Raising their hands, answering and/or asking questions/ discussing/discussing/looking at the demonstration/ writing notes and/or making drawings.
7	• FDBK+G/A+WRTN • LE+G/A+WRTN • LE+WRTN+G/A+VR] • LE+G/A+VR+ANLG]	Looking at the lecturer/demonstration/board/ writing notes and/or making drawings
8	• [ANLG+G/A+Q] • [Q+ FDCK+G/A]	Raising their hands answering and/or asking questions/discussing/ looking at the lecturer /demonstration/writing notes and/or making drawings
	UNGROUPED: Distinct forms of student engagement	
9	• [WRTN+Q]	Looking at the board/ raising their hands, and/or asking questions /discussing/writing notes and/or making drawings
10	• [G/A+Q]	Looking at the demonstration/ raising their hands, and/or asking questions /discussing/ writing notes and/or making drawings /
11	• [LE+ VR]	Looking at the lecturer/**screen**/ writing notes and/or making drawings
12	• [LE+ WRTN+Q]	Looking at the lecturer/board /raising their hands, answering and/or asking questions/discussing/ writing notes and/or making drawings
13	• [LE+ G/A+VR+Q]	Looking at the lecturer/demonstration/screen/raising hands, answering and/or asking questions/ discussing/ writing notes and/or making drawings
14	• [FDBK + LE+ G/A + VR]	Looking at the lecturer/demonstration/ screen/writing notes and/or making drawings

The fourteen different patterns of student engagement that manifested from the different MMO types across the levels are shown again below to help the reader to easily see or identify the key differences.

1. Looking at the lecturer/writing notes and/or making drawings
2. Looking at the lecturer/screen/ writing notes and/or making drawings
3. Looking at the lecturer/demonstration/ writing notes and/or making drawings
4. Looking at the lecturer/board/writing notes and/or making drawings
5. Looking at the lecturer/demonstration/board/ writing notes and/or making drawings
6. Looking at the lecturer/demonstration/ screen/writing notes and/or making drawings

7. Looking at the lecturer/ raising their hands, and/or asking questions/discussing/writing notes and/or making drawings
8. Looking at the lecturer/board /raising their hands, answering and/or asking questions/discussing/ writing notes and/or making drawings
9. Looking at the lecturer/demonstration/screen/raising hands, answering and/or asking questions/ discussing/ writing notes and/or making drawings
10. Looking at the screen/ raising their hands, and/or asking questions /discussing/ writing notes and/or making drawings
11. Looking at the demonstration/ raising their hands, and/or asking questions /discussing/ writing notes and/or making drawings
12. Looking at the board/ raising their hands, and/or asking questions /discussing/writing notes and/or making drawings
13. Raising their hands answering and/or asking questions/discussing/ looking at the lecturer /demonstration/writing notes and/or making drawings
14. Raising their hands, answering and/or asking questions/ discussing/looking at the demonstration/ screen/ writing notes and/or making drawings

The above findings revealed that some SE combinations or MMO types, despite their levels, as revealed by the overlaps in Table 9.3 above resulted in identical patterns of student engagement in the biology lectures. Even so, despite the varying degrees of complexity observed across these patterns that showed how students were engaging during a MMO, it became apparent that there were fundamentally six forms of student engagement constituting these patterns, prompted by the manifesting MMO types in the biology lectures. These six forms of engagement were (i) students raising hands, (ii) responding to questions, (iii) posing questions, (iv) engaging in discussions, (v) participating in writing and/or drawing, (vi) looking at the screen and/or lecturer or demonstrations. The sub-sections below aimed to explore and unpack the impact of the above identified forms of student engagement during manifesting MMOs in the lectures.

In the previous analytical chapters, laughter and student presentation were the other two manifestations of student engagement that were identified but were not included in the above list. Although laughter was observed in all lecturers, it was interpreted as an indicator of emotional engagement, which also revealed that all the lecturers were able to establish a positive environment during the manifestation of MMOs, aligning with their shared teaching and learning philosophy of constructivism. This view is also supported by Brown (2014) who argues that laughter is integral to a constructivist learning environment, offering potential justification for these findings. Another form of engagement was the students' group presentation that was identified in Dr Chris' case (Chapter 5). Despite its occurrence in only one lecture, this MMO was key in fostering peer learning as again explained (sub-section 9.2.2) below.

9.2.1. Students raising their hands/ answering and or asking questions/ discussing

In all lectures, it was noted that when lecturers asked questions (a form of talk), regardless of whether these questions were open or closed or based on SE as shown in Table 9.3 above, students were

frequently observed raising their hands and often responding. This student behaviour was interpreted as a sign of engagement during the manifesting MMO, as illustrated in Figure 9.1 below, which was taken from Dr Chris's lecture 1, episode 1.

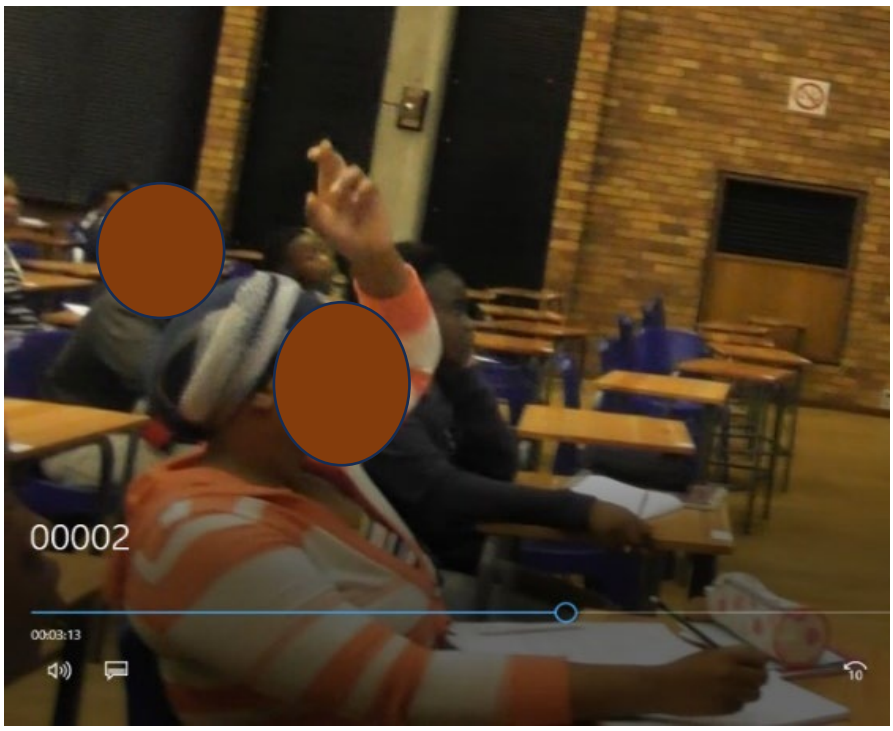


Figure 9.1 A student raising their hand to respond to a question in Dr Chris's lecture

This result meant that any MMO type that involved questions had the potential to prompt students to raise their hand and possibly respond if selected by the lecturer. As a result, the student's response would often result in a whole class discussion and/or Q&A segment. That is why Tanner and Allen (2005) emphasise the significance of questions as valuable pedagogical instruments for stimulating active participation among students. This perspective is further affirmed by Dr Molly, who, during the VSRI, expressed that she used questions to "…*actively involve and engage the students*…" Additionally, Drs Ellen and Moses acknowledged the use of questions in also promoting thinking about the concepts among students (see Chapter 7 & 8).

While all the lecturers used questions to actively involve students in their lectures, the findings indicate that there were differences in the types of questions used by the various lecturers as evidenced by Table 9.4 below.

Table 9.4. Summary of the question types asked in the different lectures

Lecturers	Dr Chris	Dr Molly	Dr Moses	Dr Ellen	Total frequency across all the lectures
Open-ended questions	12	39	10	40	**121**
Closed-ended questions	55	34	50	55	**174**
Total frequency across each lecturer's lectures	67	73	60	95	**295**

The findings presented in Table 9.4 above shows that Drs Ellen and Molly predominantly asked open-ended questions in their teaching approach, whereas Drs Moses and Chris primarily used closed-ended questions. As a result, in the lectures conducted by Drs Molly and Ellen, students not only responded to questions but also initiated or posed questions themselves, resulting in dialogic discussions between the student and lecturer. This finding highlights the central role that open-ended questions have in stimulating students' active engagement during manifesting MMOs. These results also reveal that lecturers need to take into consideration their questioning styles as they seem to be fundamental to the manifestation of MMOs that foster dialogic interaction during lectures.

Even so, in all lectures, there were occurrences where students' engagement with questions was lacking. This lack of engagement was evident when lecturers would pose questions and received no response or even 'murmuring' from students. The 'murmuring' in this study was often interpreted as another indication of students' uncertainty or a 'thinking out loud' mechanism for formulating a response. This trend was consistently observed across all lectures and at all levels, particularly when lecturers did not allow sufficient time for students to contemplate or process the question posed. It is worth noting that Dr Moses' lectures exhibited a higher frequency of such instances compared to other lecturers. These results emanating from Dr Moses case, could be explained by his utterances during the VSRI, when he was questioned about his practice of not affording students adequate time to respond to questions and instead providing them with answers promptly. In response, he explained that:

"…. you see because I know these students do not like to answer questions…although ideally it is important for a lecturer to wait for them to respond but I just end up giving them the answers because time is also not on our side…"

Dr Moses' statement reveals that students' negative attitudes towards questions and time constraints can hamper on lecturer's providing the necessary 'wait time' after posing questions, despite its importance in facilitating student engagement with questions (Iksan & Daniel, 2015). That is why when lecturers pose questions, it is imperative to allow students ample time for thoughtful engagement with the question so they can formulate appropriate responses.

9.2.2. Students engaging in discussions and small group presentations

Another form of active participation that was identified was students' involvement in discussions. The cross-case analysis demonstrated that in all lectures, students actively participated in discussions. These findings can be substantiated by the fact that all lecturers were observed leading whole-class discussions by posing both open and closed-ended questions, as previously mentioned. As expected, based on their questioning styles, Drs Ellen and Molly's lectures were characterised by in-depth responses which reflecting their different viewpoints, thus resulting in 'rich' discussions. While Drs Chris and Moses's discussions were characterised by brief one-word responses. These results further show the significant impact questioning styles have on the 'richness' of manifesting discussions during MMOs. Even so, these findings support Mumuni's (2017)'s postulation which emphasises the importance of guided discussions in enabling students to verbalise their thinking about the presented content.

However, it is worth noting that peer-to-peer discussions were only observed in the lectures of Drs Ellen, Chris and Moses, unlike in Dr Molly's lectures. This divergence can be attributed to the fact that both Drs Ellen and Moses intentionally designed or planned activities that were aimed at facilitating peer discussions in their lectures. For instance, Dr Ellen introduced a series of activities known as 'questions of the day' and according to her explanation to students in lecture 1, these questions were for:

"…especially for those of you who come in early…so that you can start thinking about what we will be covering in the lecture… then you can start discussing those questions with your peers, as they will be important to introducing you to the importance of the lecture."

Similarly, Dr Moses also planned an activity in which students had to work with their peers to draw and label the human urinary system and provide the functions of the provided structures as explained in Chapter 7. Both the lecturers' MMO highlights the significance of deliberately planning activities that are aimed at engaging students in discussing the content, thus fostering collaborative learning among students. It was interesting to see most of the students in Dr Moses' lecture engaged with this peer activity particularly because of the low levels of engagement that they continuously displayed in the lectures. The result can be justified by Vargas-Hernández & Vargas-González (2023)'s argument that student-student interactions enable them to 'freely' share ideas and experiences using a common 'peer language' to unpack and translate complex content during learning that they would not normally use with their lecturers. Also, this heightened engagement can be attributed to the active monitoring of students' participation by Dr Moses during the activity, although his lecture venue layout did not permit him, similar to Dr Ellen, to easily walk between rows and reach the students seated at the back like in Dr Chris's venue.

Even so, Dr Moses revealed during the VSRI that he did this "…*to ensure that the students were engaging with the activity…*"

In the same light, Dr Ellen also mentioned during the VSRI that she monitored her students' progress to:

"*…hear how they are thinking and understanding the concept...and to get to know them better…but there will be some students who choose to talk about their own things because you can't reach to all of them".*

Both the lecturers' responses highlight the importance of actively moving around the lecture to ensure students are actively participating in tasks. Dr Ellen's response further highlights the importance of monitoring, which allows lecturers to gain a deeper understanding of their students' individual needs. This insight can inform the design of instructional activities tailored to meet students' needs, ultimately enhancing the overall manifestation of MMOs. Additionally, Dr Ellen's response further stresses the idea that contextual factors and students' willingness to learn, all play a crucial role in how students engage with the manifesting MMOs in lectures.

Although Drs Molly and Chris did not necessarily plan teaching activities that were explicitly designed to promote peer discussions during their lectures. They incorporated activities that resulted in the manifestation of MMOS for their students to work individually as well as collaboratively. For example, Dr Chris involved his students in drawing a 2D animal cell and asked students to work in small groups to design presentations based on the structure and function of a particular animal cell organelle, as explained in depth in Chapter 5.

On the other hand, Dr Molly gave students a group-based assignment focused on designing a model illustrating different phases of mitosis, which was more of an expanded MMO in her case. These results stress the value of involving students in MMOs that foster collaborative learning, both within and beyond the lecture settings as they foster student engagement with the content. These findings further support Vygotsky's (1975) assertion that the construction of meaning is a social process occurring on both the individual and social dimensions. These results can be again justified by the fact that all the lecturers ascribed to a constructivist approach, which places emphasis on student-centered learning through individual and collaborative social activities.

9.2.3. Looking at the lecturer/screen/demonstration resulted in drawing and writing

As earlier mentioned, in all the lectures, students were predominantly observed taking notes, even though Dr Molly did not use the SE of writing and drawing in her lectures. Notetaking in this study also indicated student engagement and was usually observed during or after the lecturer's explanations, discussions, demonstrations, and peer presentations as evidenced in Figure 9.2 below extracted from Dr Chris' lecture 1.

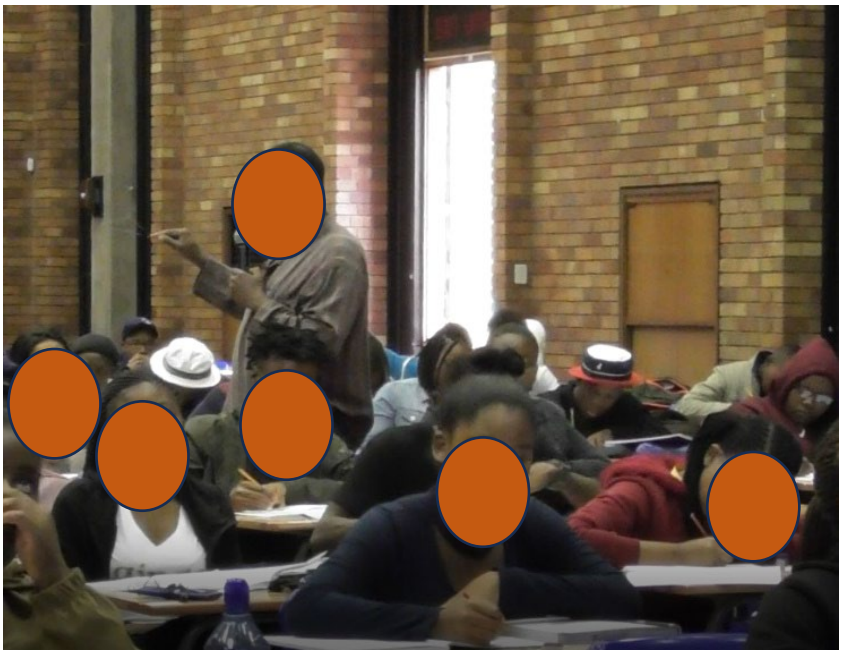


Figure 9.2 Student engaged in writing in Dr Chris's lecture 1

Although notetaking seemed to be an activity that was largely self-initiated by certain students, Drs Chris, Moses, and Ellen intentionally involved students in writing and/or drawing activities into their lectures. In one of Dr Chris's lectures, a manifesting MMO that involves students in writing and drawing involved the students in drawing and labelling a 2D animal cell. When Dr Chris was asked why he asked the students to make a 2D drawing of the animal cell during the VSRI, he mentioned that:

"I really wanted to understand how much my students know about these abstract structures and to develop their biological drawing skills as they will become future teachers."

Dr Chris's view aligns with Bartoszeck et al.'s (2017) assertion that both writing and drawing are indispensable tools for promoting biological literacy and effective instructional methods. Generally, these findings demonstrate a shift in pedagogical practices among lectures, as they appear to challenge the perspective put forth by scholars, such as Bartoszeck et al.'s (2017) that many lecturers often overlook the value of writing as an instructional tool in HE environments. These results suggest that writing and/or drawing can result in MMOs that can effectively engage students. Therefore, lecturers should intentionally plan and incorporate activities that encourage students to engage in writing and/or drawing during lectures.

9.2.4. Looking at the screen/ board/lecturer/ demonstration

Wu and Schunn (2023) explain that students who are seated while attentively listening or observing a teacher can be classified as passive participants. In this study, across the lectures, students were also observed seated and directing their attention toward the screen when a lecturer displayed an image, or looking at the lecturer when demonstrating, explaining, or providing feedback and in this study all this was interpreted to signal students' engagement. As revealed in Table 9.3 these forms of engagement

were promoted by gestures and/or actions, writing and/or drawing, lecturer explanations and feedback. It is worth mentioning that all lecturers incorporated various visual representations which included colourful images, bolded/bulleted/brief text, animated images, and many other into their PowerPoint presentations which resulted to the manifestation of MMOs in their lectures. What was notable about most of these images was that all the lecturers made use of colourful images which are known to capture students' attention (Brandstetter et al., 2017). As mentioned earlier, all lecturers employed various pointing devices to guide students' attention toward specific elements within the images which could also explain why the students engaged with these images. Therefore, MMO that include GA, WRTN, VR and LE promoted student engagement.

Another interesting observation is that Drs Moses, Ellen, and Chris, unlike Dr Molly, did not only rely on images in their PowerPoint presentations but also used freehand drawings (examples appear in Chapters 5, 6, and 8). These drawings elicited student engagement in ways similar to colourful projected images, possibly because they served as tools for concretising abstract concepts (Brandstetter et al., 2017). In addition to drawings, lecturers sometimes employed **demonstrations**, such as showing physical objects or modelling processes, which further anchored abstract ideas in tangible experiences. Together, these visual and practical strategies highlight that representations in multiple forms such as projected images, freehand drawings, and demonstrations, are all vital in the manifestation of MMOs that foster cognitive engagement during meaningful learning.

9.3. The relationship between MMO types, students' learning preferences and levels of students' engagement

The above case-by-case analysis revealed that students' levels of engagement seemed to be impacted by the types of MMOs manifesting. Table 9.3 above revealed that there were similarities in the forms or patterns of engagement prompted by MMOs types in the various levels, there seemed to be a general increase in the number of students who were engaged at any given time as the complexity of the MMO types increased. MMO types occurring at level 1 appeared to engage a smaller number of students compared to those at levels 2 and 3. This observation at level 1 was highlighted by the keyword ***"few"*** which denotes the number of students that were seen in the video engaging during a particular MMO type as depicted by Table 9.2 above. The possible reason for this result might be that MMO types at level 1 which were a result of a combination of only two different SEs would at most engage or cater for, at most, two types of learning preferences. In Table 9.2 above, at level 2, a shift was noticeable, with MMO types engaging from just a "***few"*** to ***"more than half"*** or even ***"most"*** students and this was explained by the fact that at this level, the MMO types manifested from a combination of three different SEs which meant that there were multiple avenues for engaging students thus catering for more types of learning preferences as compared to those appearing at level 1. Level 3 MMO types appeared to accommodate most of the students, and this was evidenced by the keywords ***"most"*** or even ***"all"***

as shown in Table 9.2 above. These results could be explained by the fact at level 3, the MMO types manifested from four different SEs therefore MMO types at this level were deemed to be complex in nature than those appearing in levels 1 and 2. These results therefore suggest that as the MMO type levels increase there is also an increase in students' engagement and this relationship is graphically represented by Figure 9.3 below.

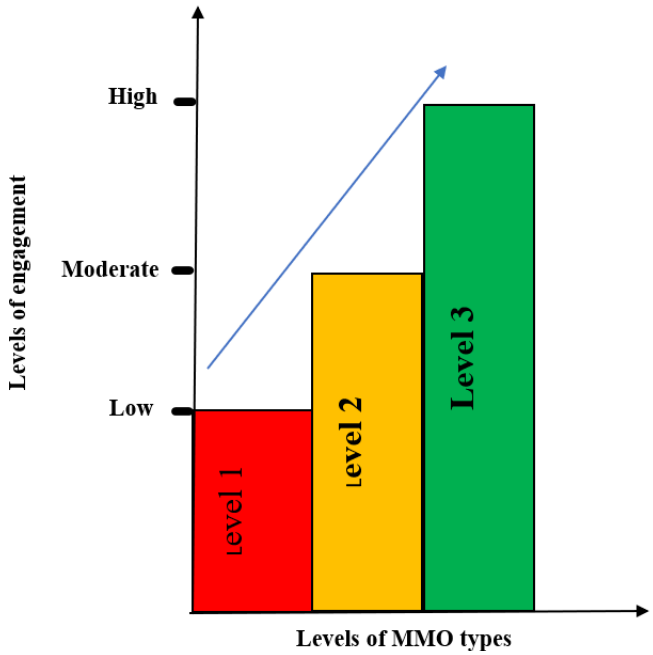


Figure 9.3 The relationship between levels of MMO types and students' levels of engagement

These results can be further justified by the fact that different students have different learning preferences. Some students prefer visual learning, others auditory, some excel when engaged in reading and writing, while others thrive through kinaesthetic or hands-on experiences, or a blend of these modalities as revealed by Shaidullina et al. (2023). The relationship between the MMO-type levels and student engagement is further summarised by Table 9.5 below.

Table 9.5 Summary of the relationship between levels of MMO types and students' levels of engagement

Levels	1	2	3
Criterion	**Basic**	**Average**	**Complex**
MMO type	One or two SE combinations were used.	Three SE combinations were used.	Four SE combinations were used.
Students' Engagement	SE combinations are likely to engage one group of students with a specific learning preference.	SE combinations are likely to engage more students as the combinations cater to two or three learning preferences.	SE combinations are likely to engage most of the students as the SE combinations cater to three or four learning preferences.

These results support the findings of the systematic review conducted by Shaidullina et al. (2023) in the HE context, which found that when lecturers used numerous teaching strategies, they were able to cater for their students' diverse learning preferences. This results in better retention of information which improves their overall academic performance. However, in this study, I cannot truly account for the impact of the manifesting MMOs on the students' overall learning and general academic performance, as this was beyond the scope of the research. What the results do highlight is the importance of lecturers employing diverse SEs as a means of promoting the manifestation of complex MMO types, which have a higher chance of engaging students with the content being taught. This is particularly relevant to biology, where abstract and highly visual concepts (e.g., molecular processes, cellular structures, ecological systems) often require multiple representations for meaning making. It is also significant in the context of a multicultural urban university, where students come from varied linguistic, cultural, and educational backgrounds. Such diversity means that students draw on different prior knowledge frameworks, conceptual repertoires, and epistemic traditions when engaging with biology. In this context, employing a wide range of SEs is not merely pedagogical variety but a necessary means of creating equitable access to complex disciplinary knowledge. Thus, the manifestation of complex MMOs must be understood in relation to both the epistemic demands of biology content and the multicultural, multilingual realities of the urban HE environment

9.4. Conclusion

The findings from the above cross-case analysis confirmed that all four categories of SEs emerged. As shown in Figure 10.1(see Chapter 10), these are talk (yellow circle), visual representations (purple circle), gestures and/or actions (blue circle), and writing and/or drawing (red circle). In the context of biology teaching socio-cultural tools are crucial for lecturers to use in the social plane (revealed by the rectangular shapes in Figure 10.1 in the next chapter). This develops diverse MMO types that have the potential to engage students of different learning preferences. The findings also revealed that there appears to be a relationship between the SEs and the student's learning preferences, as presented by the alternating arrows at the top of Figure 10.1 (next chapter). MMOs resulting from talk mostly accommodate students who prefer to learn auditorily (both SE and learning preference represented by the yellow circles). MMOs supported by visual representations accommodated students who prefer to learn visually (both SE and learning preference represented by the purple circles). MMOs supported by writing and/or drawing appeared to cater for students who prefer to learn through reading (both SE and learning preference represented by the red circles), while those who prefer to learn through writing seemed to be supported by all SEs. Some of the students in all the lectures were seen to continuously write notes despite the manifesting MMO type as earlier mentioned. MMOs that comprise of gestures and/or actions seem to involve the students who prefer to learn practically (both SE and learning preference represented by the blue circles).

The use of all four main categories of SEs manifested into diverse combinations depicted by arrows emanating from colour-coded circles representing SEs were all employed by the lecturers to generate diverse MMO types. These resulting MMO types were classified into three primary levels, with level 1 denoted by the red arrow, level 2 by the yellow arrow, and level 3 by the green arrow, as depicted in Figure 10.1 (see Chapter 10). Despite the overlaps in the patterns showing the forms of engagement that emerged from the manifesting MMO types, the results still indicated that the complexity of MMO types appeared to increase student engagement levels. These findings suggest that there is a direct relationship between the levels of the MMO types and students' engagement levels. This direct relationship is represented by two alternating arrows that connect to the two rectangles showing the lecturer's MMO tools and the student's MMO tools in Figure 10.1. The relationship between the levels of MMO types and students' engagement levels is visually represented in Figure10.1 in the next Chapter. This is illustrated through the right brace shape encapsulating color-coded arrows that denote the three levels of MMO types, directed toward the circle representing student engagement. The left brace shape encompasses colour-coded circles representing students' learning preferences, which also converge towards the central circle again representing student engagement.

The relationship between the levels of the MMO types and students' engagement levels can be attributed to the idea that different students have diverse learning preferences, which impact how they construct

meaning and learn, as explained by Shaidullina et al. (2023), as evidenced by the findings of this study where level 1 MMO types engage fewer students while level 3 MMO types engage almost all the students. These results dispute Jones (2017)'s argument that lectures are usually ineffective in creating active and participatory learning environments and using a repertoire of strategies geared toward engaging students. This is because according to Jones (2017) lectures are a one-way 'transmissive' method, which often ignores the differences by which students learn, preventing a deep learning experience. Consequently, the SEs can be deemed lecturer tools for establishing MMO types, which correspond to learning preferences and can also be viewed as students' tools for constructing MMOs, as depicted in Figure 10.1 in the next chapter. These findings support Scott and Mortimer (2012)'s assertion that the process of meaning making is a collaborative activity between students and lecturers.

The analysis revealed both similarities and distinctions in the MMO types employed by the four lecturers. Although there were minor similarities among the lecturers' teaching which was signified by a common MMO type at each level, these results can be attributed to the fact that the analysis supported by literature revealed that all the lecturers taught 'challenging' biology topics of an abstract nature, and some of the lecturers' practices were grounded in similar teaching philosophies, which was the constructivism. The constructivist approach views learners or students as active creators of knowledge rather than passive recipients of information. This philosophy was also reflected in most of the manifesting MMO types, as well as in the form of active engagements (e.g., students actively answering, asking questions, and collaborating in activities to mention a few) that manifested across the lectures. These findings indicate that the lecturers' teaching philosophies also appeared to influence the type of MMOs that manifested in their lectures, and this is depicted by the first rectangular shape located at the bottom of Figure10.1 in the next chapter.

There were notable differences in the MMO types that were identified in the four lecturers' teaching. These differences can be attributed to the different topics taught by the lecturers, students' willingness to participate as well as their year of study, and variations in lecturers' planning and levels of creativity. Of the four lecturers, Dr Ellen was the only one who based her planning on the TSPCK framework which enabled her to intentionally plan not only 'rich' SEs but intentional or targeted MMOs involving analogies, peer discussions, modelling, and storytelling to mention a few. All these were instrumental in exposing, as well as engaging students to conceptually understand the complex terminology, the relationships that exist among concepts and the sources of misconceptions surrounding the topic of genetics. These findings illustrate Mavhunga and Rollnick's (2013) foundational insight that TSPCK is crucial for addressing the unique conceptual challenges of specific biology topics, thus enabling lecturers to transform subject matter knowledge into teachable forms that are accessible to students. This divergence can also be attributed to Dr Ellen's self-study practice, which influenced the range of MMO types evident in her lectures. This aligns with Fischer (2013)'s argument that effective teaching in HE requires lecturers to possess deep content knowledge and ground their practices in research. These

findings showed that the lecturer's methods and knowledge of the topic of planning also influence the type of MMOs that they create for their students, and this relationship was represented by the second rectangular shape at the bottom of Figure 10.1 in the next chapter.

The findings of this study indicate that the teaching context and available resources influenced the MMOs employed by the lecturers as revealed by the third rectangular shape at the bottom of Figure10.1 in the next chapter. For example, Dr Chris who was teaching in a large venue used a mobile microphone and moved around the lecture hall, while the other three lecturers who taught in relatively smaller venues lectured without the need for such a piece of equipment.

The findings of this study as revealed above showed that the lecturer's teaching methods and knowledge of the topic were somewhat also influenced by their philosophies and contextual factors as represented by the two arrows emanating from the first and third rectangles at the bottom of Figure 10.1. in the next chapter.

In summary, the findings of this study support Taylor's (2014) assertion that meaning making is a complex process for which there is no one-size-fits-all approach. Lecturers, like teachers, must draw on their professional knowledge, such as PCK or TSPCK, to promote the manifestation of 'rich' MMOs in their lectures. The study further suggests that the move from transmissive methods toward more creative and multimodal approaches is not merely a formal requirement, but a transition shaped by multiple factors. These include the lecturer's awareness of student needs, accumulated teaching experience, depth of content knowledge, available time, resources, and their capacity for reflexivity in practice. In this sense, adopting approaches that foster 'rich' MMOs reflects both explicit pedagogical choices and the influence of contextual and experiential factors, rather than a simple or automatic shift.

The next chapter presents the answers to the research questions, offers a reflection on the key takeaways from my doctoral journey, and discusses the study's limitations. It further outlines the implications of the findings for biology education and provides recommendations for future research and practice.

Chapter 10

Key conclusions, limitations, and recommendations for future research

10.1. Introduction: Overview of the study

This study aimed to explore the manifestations of meaning making opportunities in higher education biology classrooms, focusing on four case studies of four biology teacher educators. In this study, I coined the term "meaning making opportunity" to refer to a teaching and learning 'chance' that permits the students to engage with and make sense of the knowledge being presented. Investigating meaning making opportunities was motivated by the realisation that despite studies on opportunities to learn meaning making and sense-making, there is a significant gap in understanding how these opportunities that result in meaning making manifest in biology lectures. Consequently, not much is known about whether or not biology lecturers are in a position of promoting meaning making opportunities that enhance their students' overall understanding of biology content. According to Loughlin and Lindberg-Sand (2023), lecturing is often described as a one-way approach for disseminating information, thus, questions are raised about its effectiveness in fostering meaningful learning experiences. The analysis of the literature consulted in this study reveals that the biology topics covered by the four teacher educators (cell biology, mitosis, animal tissues, osmoregulation, excretion, genetics and meiosis) are well-known for presenting challenges for both teachers and learners due to their abstract and complex nature. Hence, researching and exposing types of meaning making opportunities that manifest in lectures on these challenging topics was deemed fruitful. Documenting meaning making opportunities was seen as potentially useful in providing insights into strategies that can be used by biology teacher educators to facilitate deeper understanding and engagement, particularly in initial biology teacher professional development programmes.

The study was underpinned by two primary theoretical frameworks, sociocultural theory and meaningful learning theory. These frameworks were selected for their complementary perspectives on learning as a social activity and cognitive development. Thus, the integration of these two theories was used to explore the dynamics of the manifestation of meaning making opportunities in biology lectures. The meaning making opportunities were explored by examining how biology teacher educators draw on students' prior knowledge and make use of cultural tools (social exchanges) and social interactions to promote meaning making opportunities. This approach not only emphasised the interconnectedness of the two theoretical frameworks but also highlighted the innovative application of these theories in the context of the manifestation of meaning making opportunities in biology education.

The analytical framework that was constructed in this study consisted of social exchanges, various students' forms of engagement, and learning preferences. All three of these constructs provide a clearer and more practical approach for identifying and documenting manifesting students' meaning making opportunities in biology lectures. The reason for this was these social exchanges were instrumental in revealing the various socio-cultural tools employed by biology teacher educators that prompted the manifestation of meaning making opportunities in their lectures. Interestingly, when re-watching the video recordings of the lectures, I observed that within a single meaning making opportunity, engagement levels varied significantly across different students. This variability prompted me to take a closer examination of student engagement and their underlying cause(s). It became evident that student learning preferences and engagement were critical factors for the uptake of manifesting meaning making opportunities in biology lectures.

One main research question and three sub-research questions guided this study as detailed below.

Main research question

How did biology teacher educators facilitate the manifestation of meaning making opportunities during their lectures?

Sub-questions

1. *What meaning making opportunities were facilitated by biology teacher educators in their lectures?*
2. *What forms of student engagement (if any) were elicited by the biology teacher educator during the manifesting meaning making opportunities?*
3. *What were the factors that promoted or hindered the manifestation of meaning making opportunities that were facilitated in the biology teacher educators?*

To gather data that would help me to answer these research questions, the study consisted of four cases as follows:

- Case study 1 based on Dr Chris's Cell biology lectures
- Case study 2 based on Dr Molly's lectures on mitosis and animal tissue
- Case study 3 based on Dr Moses's lectures on osmoregulation and excretion
- Case study 4 based on Dr Ellen's' lectures on genetics and meiosis

The data for this study was gathered through video and audio-recorded lecture observations and video-stimulated recall interviews. Each case study was analysed individually, using both deductive and inductive methods. The deductive analysis was informed by the analytical framework built on social exchanges, student engagement, and learning styles, while the inductive analysis considered the new

patterns emerging from the data. This dual approach allowed for a comprehensive understanding of each case in greater detail. Subsequently, a cross-case analysis, detailed in Chapter 9, was conducted to identify similarities and differences in the identified meaning making opportunities that emerged across the four cases which led to the development of a meaning making opportunity model presented in Figure 10.1 below. I describe this model in some detail as it is a key contribution from this study about how meaning making opportunities manifest in lectures at a university level.

10.2. Answering the research questions

The subsections below seek to respond to the one main and three sub- research questions that were stated earlier, which were all crucial in guiding this study.

10.2.1. Answering the main research question: How did biology teacher educators facilitate the manifestation of meaning making opportunities during their lectures?

This study revealed that the manifestation of meaning making opportunities in biology lectures is dynamic and multifaceted. The manifestation of meaning making opportunities in the biology lectures mainly rested in the biology teacher's ability to foster meaningful social interactions by drawing and building on students' prior knowledge and leveraging their understanding of who the students are. Thus, the manifestation and 'richness' of meaning making opportunities were predominantly influenced or brought out by an amalgam of the following interrelated factors: the teacher educators' levels of planning and creativity in selecting appropriate teaching and learning strategies, knowledge of the topic, pedagogical content knowledge considerations, teaching philosophies language issues, and overall student attendance and/or participation as shown in Figure 10.1 and Table 10.1 below.

As shown in Figure 10.1 below, more complex meaning making opportunities catered for various learning preferences. These findings suggest that biology teacher educators need to simultaneously use a variety of social exchanges to promote the manifestation of meaning making opportunities in their lectures because they are crucial for creating engaging, inclusive, and effective learning environments. By using diverse social exchanges simultaneously and considering students' learning preferences, teacher educators can enhance their students' engagement during manifesting meaning making opportunities.

Despite variations in how different meaning making opportunities were classified at different levels as depicted in Figure 10.1 below, a noteworthy finding was that all these types of meaning making opportunities classified at different levels involved a component of talk. This means that talk was at the centre of social interactions as earlier indicated and hence at the centre of the meaning making opportunities. The results suggest that the type of talk used by the biology teacher educators matters in the manifestation of 'rich' meaning making opportunities. In other words, the types of questions, explanations, and feedback used by biology teacher educators are crucial in the manifestation of meaning making opportunities in their lectures. Explanations, feedback, and questions can be seen as

‘drivers’ of social interactions which bring out meaning making opportunities and possible meaning making. However, the findings of this study revealed that talk on its own is not adequate for the manifestation of meaning making opportunities, but it is enriched and complemented by the simultaneous use of engaging visual representations, analogies, mnemonics, and/or gestures and actions.

The findings of this study revealed in Figure 10.1 and Table 10.1 below further showed that for meaning making opportunities to be ‘rich’ and relatable, teacher educators needed to elicit and build on the student’s prior knowledge. They should also have awareness of any possible misconceptions that students may have about a certain concept, which may emanate from their high school teaching and associated textbooks used. These results highlighted the need for biology teacher educators to rely on sources beyond textbooks and to rather keep abreast with current research around their subject of specialisation. The research-informed pedagogy can be used by biology teacher educators to equip themselves with insights into possible misconceptions, challenges, and effective teaching strategies for efficiently capitalising on their students’ prior knowledge and laying a solid foundation for constructing new knowledge.

Increased complexity of meaning making opportunities did not always translate into ‘rich’ meaning making opportunities. Rather, ‘rich’ meaning making opportunities, as illustrated by Figure 10.1 and Table 10.1 below, relied heavily on educators' meticulous planning, which encompassed the creative selection of visuals (e.g., models, analogies, demonstrations), comprehensive concept explanations, eliciting student prior knowledge, and rectification of misconceptions as well as other PCK and/or TSPCK knowledge domains. These findings revealed that when biology teacher educators plan their lectures, what they are planning are the social exchanges, as they would often think about various teaching and learning strategies, such as visuals, models, explanations, and assessments, that they will use to enhance their lectures. However, it is important to note that they do not necessarily plan for meaning making per se. Instead, meaning making opportunities often manifest because of implementing the planned social exchanges during the lectures. Therefore, the need for planning carefully thought-out social exchanges cannot be over-emphasised.

Importantly, linking these findings to the broader higher education teaching and learning discourse, the DHET National Framework for Enhancing Academics as University Teachers (2018) explicitly highlights this dual challenge: the need for curriculum renewal alongside the strengthening of pedagogy through ongoing professional development, recognition, and the establishment of teaching-focused communities of practice. From this perspective, biology teacher educators are not separate or exceptional but situated firmly within the broader higher education system, where they are expected to adopt scholarly approaches to teaching and learning (SoTL) (Kern et al, 2025). This involves drawing on current disciplinary research, engaging critically with pedagogical literature, and contributing to

communities of practice that advance university teaching. Thus, this study contributes to that agenda by showing that the manifestation of meaning making opportunities (MMOs) in biology lectures is closely tied to how teacher educators design and enact their teaching in ways that align with SoTL principles (Kern e al., 2015). Rich MMOs emerge when lecturers engage in research-informed pedagogy that equips them with insights into students' prior knowledge, possible misconceptions, and effective teaching strategies. In this way, the study not only illuminates how MMOs materialise in disciplinary practice but also affirms the centrality of SoTL in enhancing teaching and learning within higher education.

As revealed by Figure 10.1 below, the biology teacher's adoption of teaching philosophies was central to how the meaning making opportunities manifested in their lectures. In particular, the findings showed that the biology teacher educators' adoption of a constructivist approach shaped the manifestation of meaning making opportunities in their lectures. This encouraged active learning and knowledge construction through interactive activities such as peer discussions and group work all of which provided students with a space for collaborative sharing and formulating of ideas. These activities promoted collaborative engagement, despite the students' linguistic backgrounds. There findings reveal that a teacher educator's teaching philosophy matters as it influences the kind of pedagogical factors that they will consider when planning their lectures, the social exchanges that they will plan for and hence the meaning making opportunities that will manifest in their lectures.

All the above-mentioned factors served to promote the manifestation of meaning making opportunities and foster meaningful learning experiences. Nonetheless, when not properly considered during the planning phases, these factors have the potential to hinder the effectiveness of the manifesting meaning making opportunities in biology lectures.

10.2.1 Answering Sub-RQ1: What meaning making opportunities were facilitated by biology teacher educators in their lectures?

As illustrated in Figure 10.1 below, there were various meaning making opportunities that manifested across the biology lectures, each centered around 'talk'. The different meaning making opportunities were categorised into three distinct levels based on the complexity of social exchanges combinations involved, as explained below:

- **Level 1 MMOs** manifested from any two social exchange combinations and were likely to cater one or two learning preference(s). These MMOs were basic in nature and provided limited diversity in instructional strategies.
- **Level 2 MMOs** manifested from any three social exchange combinations, catering to two or three different learning preferences. These MMOs were more complex and likely to engage a broader range of students compared to Level 1.

- **Level 3 MMOs** originated from any four social exchange combinations, addressing three or four learning preferences. These were the more complex MMOs, designed to engage most students with different learning preferences.

The findings of this study revealed that Level 1 MMOs were the most prevalent across the biology lectures. Specifically, in three out of the four lecturers the manifesting meaning making opportunities were predominantly at Level 1, suggesting a reliance on basic teaching strategies that catered to a limited range of learning preferences. The exception was Dr Ellen, whose lectures were characterised by Level 2 MMOs, indicating a more balanced and diversified approach to student engagement.

This distinction in the levels of the manifesting meaning making opportunities in the biology lectures was particularly notable given that all lecturers reported planning their lectures during the Video-Stimulated Recall Interviews. However, only Dr Ellen mentioned that she employed a specific framework (TSPCK) for planning her lectures and incorporated research-driven, creative strategies into her instructional design. This approach likely contributed to the complex meaning making opportunities that manifested in her lectures.

These results highlight the critical role of intentional planning of lectures, continuous research, and creative pedagogical practices in enhancing manifesting meaning making opportunities. The findings suggest that biology lecturers should invest in more structured, research-informed lesson planning to diversify the types of meaning making opportunities that manifest in their lectures, thus potentially engaging a wider spectrum of students and possibly promote understanding of biological concepts.

10.2.2. Answering sub-RQ 2: What forms of student engagement (if any) were elicited by the biology teacher educator during the manifesting meaning making opportunities?

The conceptualisation of student engagement was drawn from Fredricks et al. (2004), who described engagement as a multidimensional activity composed of three main forms, viz. (i) affective-emotional engagement (ii) cognitive engagement and (iii) behavioural engagement. Following this, student engagement in this study was signified in seven ways: (i) raising hands, (ii) responding to questions and/or posing questions, (iii) discussions, (iv) writing and/or drawing, (v) looking at the screen and/or lecturer or demonstrations, (vi) listening to the lecturer and/or peers, and (vii) delivering presentations. The first three forms of engagement which involved students' raising hands, asking or answering questions, and participating in discussions were primarily prompted by the manifestation of MMOs involving questions, regardless of their complexity. Notably, open-ended questions often encouraged students to ask their own questions and engage in discussions, whereas closed questions typically elicited brief responses. When MMOs involved visual representations, gestures and/or actions, students were frequently observed looking at the screen or demonstrations, indicating engagement with visual

cues. Similarly, the manifestation of MMOs that included explanations or questions often resulted in students actively listening to the speaker. In Dr Chris' lectures, students were required to present in small groups, leading to the manifestation of MMOs that fostered collaborative learning among students.

As shown by the Figure 10.1 below, these signs of engagement further assert that meaning making is both a cognitive and social endeavour. This takes into consideration that listening, writing, and looking at the screen are all opportunities that facilitate cognitive engagement, as students need to internalise, decode, and formulate meanings in their minds based on the content that they are seeing or hearing. On the other hand, discussions, responding to questions, and delivering small group presentations were social discourses that fostered collaborative learning between the students and teacher educators.

10.2.3. Answering sub-RQ 3: What were the factors that promoted or hindered the manifestation of meaning making opportunities that were facilitated in the biology teacher educators?

As shown in Figure 10.1 below, the promotion of meaning making opportunities in biology classrooms is influenced primarily by teacher planning and creativity in selecting appropriate teaching strategies and suitable content. Thus, the lack of teacher educators' preparation and creativity can lead to unawareness of other critical factors such as (i) students' prior knowledge, (ii) language issues, (iii) inconsistent student participation, (iv) lecture venue size, and (v) resources, all of which can hinder the promotion and effectiveness of meaning making opportunities. When teacher educators plan thoughtfully, they can creatively address and capitalise on the above-mentioned factors to promote 'tailored' meaning making opportunities in their lectures. This finding explains why a teacher educator who used Topic Specific Pedagogical Content Knowledge (TSPCK) to plan their lectures was able to promote not only complex but 'rich' meaning making opportunities even in a large class. This is possibly because the different domains of the TSPCK framework prompted the teacher educator to consider a wide range of factors when planning their lecture. Table 10.1 below provides key guidelines for how 'rich' meaning making opportunities can be promoted by biology teacher educators using the TSPCK domains.

Table 10.1. Summary of the key guidelines that can promote 'rich' meaning making opportunities using the TSPCK domains.

TSPCK domains that need to be considered →	**Leveraging Learners' Prior Knowledge involves teacher educators:**	**Understanding what makes the topic easy or difficult to understand involves teacher educators:**	**Considering Curricular Saliency involves teacher educators:**	**Selecting appropriate representations (including analogies) of subject matter for a specific topic when planning involves teacher educators:**
Pedagogical actions to be employed by teacher educators	-Recognising the importance of students' prior knowledge in effective teaching, aligned with the constructivist approach. -Using diverse strategies such as open-ended questions, visual images, demonstrations, and analogies to stimulate prior knowledge and encourage student engagement. -Proactively addressing potential language barriers and encouraging participation through various prompting and wait-time strategies. -Encouraging students to share diverse perspectives based on their prior knowledge, fostering rich interactions and meaningful learning experiences.	-Understanding the school curriculum's layout and identifying potential gaps or challenges in students' comprehension of biology concepts. -Emphasising the interconnectedness of topics within the curriculum, promoting cumulative learning and deeper understanding.	-Employing a diverse range of visual aids, models, and analogies based on familiar objects to scaffold students' comprehension of abstract concepts and to enhance visual engagements. -Ensuring that visual representations accurately reflect biological concepts and are aligned with learning objectives. -Guiding students' attention effectively to optimise focus and comprehension. -Recognising the limitations of analogies and visual aids and actively mitigating potential misunderstandings or misconceptions.	-Identifying factors that contribute to the difficulty of understanding biology topics, such as complex terminology. -Engaging students in MMOs that address linguistic challenges by visually presenting key terminologies and exploring alternative contexts. -Prioritising conceptual understanding over rote memorisation or learning by using visuals including analogies and demonstrations to deepen student comprehension. -Foster critical thinking skills by encouraging students to interpret analogies and demonstrations in ways that reflect their authentic understanding.

10.3. Theoretical and Conceptual Contribution of the study: Meaning making opportunity model

This section provides a description of the meaning making model depicted in Figure 10.1 below. It theoretically and conceptually provides insights how meaning making opportunities manifest in biology lectures at a university level, and therefore crucial in answering the main and sub-research questions of this study.

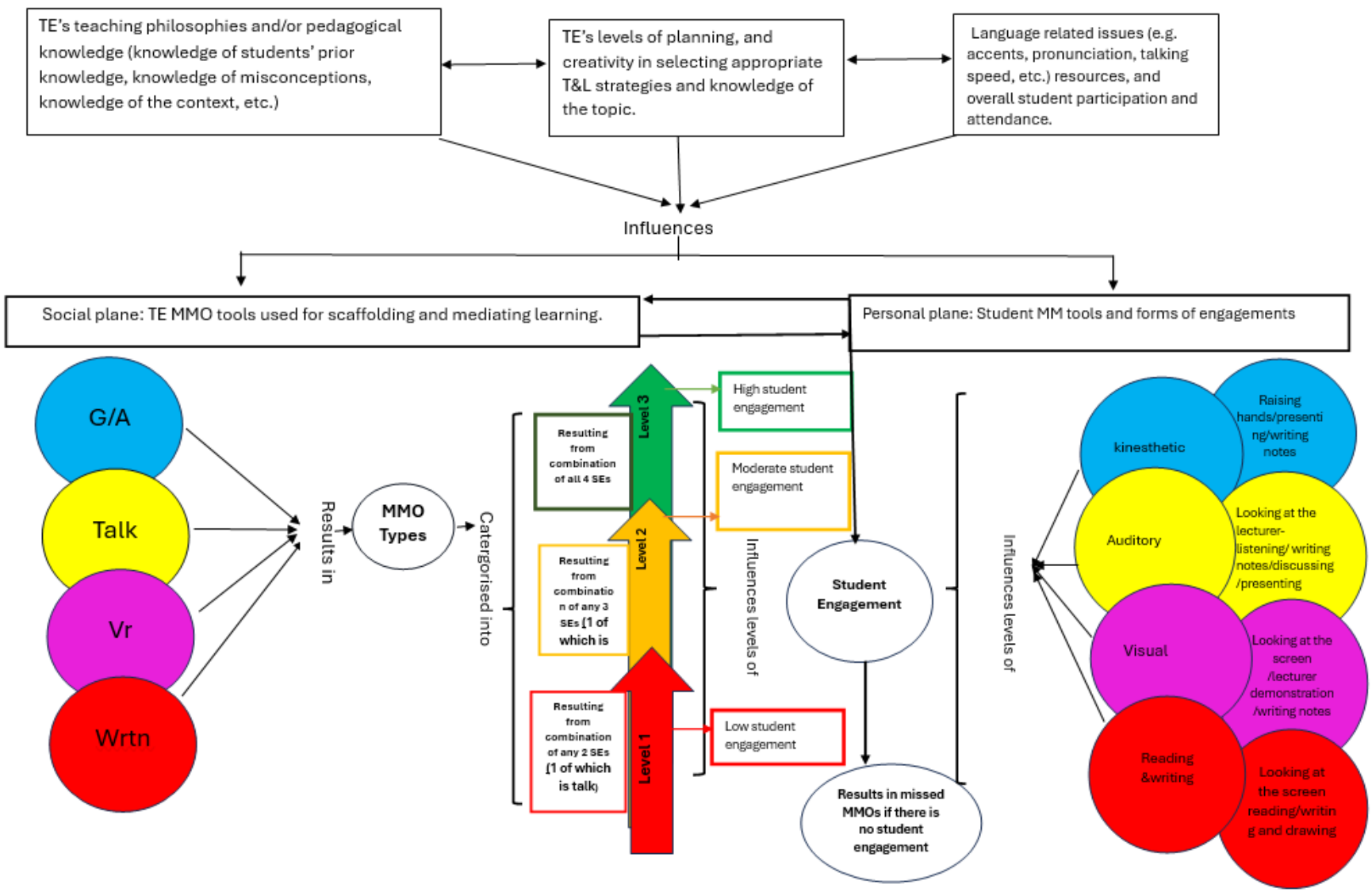


Figure10.1 Meaning Making Model

As previously explained, the concept of a meaning making opportunity was first conceptualised in this study as there was limited existing knowledge about how these opportunities manifest, especially in lectures. The new knowledge presented reveals that meaning making opportunities do not occur by chance but result from deliberate planning and the creative use of social exchanges by teacher educators as depicted in Figure 10.1 above. Although social exchanges were crucial in the manifestation of meaning making opportunities, their 'richness' was influenced by several interrelated factors. Central to this was the teacher educator's level of planning and creativity, which was closely tied to other factors such as their philosophies and pedagogical knowledge, language issues, students' misconceptions, student participation and attendance. Thus, the teacher educators' ability to creatively address these issues during planning had the potential to promote meaning making opportunities, while the lack thereof could potentially hinder the promotion of these opportunities.

The model further reveals that the co-manifestation of four social exchanges represented by the colourful circles (talk - yellow circle, visual representations -purple circle, gestures/actions - blue circle, and writing/drawing - red circle) are crucial tools used by teacher educators to scaffold and mediate learning during meaning making opportunities in the social plane. These social exchanges are vital because they complement students' various learning preferences (depicted by similar colourful circles on the left-hand side of the above model), which serve as personal tools for students to engage and formulate meanings during manifesting opportunities. Thus, the close relationship between social exchanges and students' learning preferences, is represented by the alternating arrows at the top of Figure 10.1. From the model, it can be deduced that talk primarily engaged auditory learners (both represented by yellow circles), visual representations engaged visual learners (both represented by purple circles), writing/drawing engaged students who learn best through reading (both represented by red circles), and gestures/actions engaged kinaesthetic learners (both represented by blue circles). Notably, students who prefer to learn through writing were supported by all social exchanges, as many were observed taking notes regardless of the type of meaning making opportunity.

The use of various social exchanges in different combinations resulted in diverse meaning making opportunities which could be classified into three distinct levels as summarised below.

- Level 1 (red arrow): Manifested from the use of any two social exchanges, one of which is talk.
- Level 2 (yellow arrow): Manifested from the use of any three social exchanges, one of which is talk.
- Level 3 (green arrow): Manifested from the use of all four social exchanges.

There was a direct relationship between the complexity of meaning making opportunities and student engagement levels, depicted by color-coded upward-facing arrows in Figure 10.1 above. More complex meaning making opportunities engaged a greater number of students with different learning preferences.

This revealed the need for teacher educators to plan for various social exchanges for increased chances of engaging students during manifesting meaning making opportunities during lectures.

In the subsequent sections, I will provide reflections and key learnings from my doctoral journey.

10.4 Reflections

10.4.1 Key Learnings from My Doctoral Journey as an Emerging Supervisor

Reflecting on my doctoral journey, I realise how it was a challenging, yet rewarding, experience. I initially registered in 2018, but my then supervisor left the institution that same year, causing a significant setback in my journey. In 2019, I was assigned new supervisors, and the focus of my study shifted from examining the impact of language on biology instruction to exploring meaning making opportunities during biology instruction. At the time, this shift felt like another delay, but it proved to be incredibly worthwhile. My research highlighted the critical importance of meaning making opportunities, especially in biology teacher training programs where the content often poses T&L challenges. Despite the obstacles, it was gratifying to contribute knowledge to such an important yet under-researched area with no existing articles on meaning making opportunities.

The 'Why' Behind My Doctoral Pursuit

One pivotal moment was my first meeting with Professor Marissa. She asked why I wanted to pursue a doctoral degree. At the time, I gave a rehearsed answer about expanding my knowledge in my field, but the honest reasons were that I was unemployed and desired to change my title. Professor Marissa emphasised the importance of understanding my true motivation, as it would sustain me throughout the journey. Indeed, when times got tough, my '*why*' kept me going. This exercise is something I will encourage my future doctoral students to consider deeply when undertaking this journey.

Dynamics of Two Supervisor Model: Advantages and Disadvantages

Having both a main supervisor and a co-supervisor had its advantages and disadvantages as explained in the sections below.

Disadvantages

A significant challenge was managing two sets of feedback, which was often overwhelming at times, especially when they had opposing views on a section(s) of a chapter. This often left me confused about where to start. However, regular meetings to discuss the chapters, with both supervisors present in the meeting to address the major issues, helped clear the confusion(s) for all of us. The collaborative review of each supervisor's comments enriched the feedback process and clarified the direction forward. These regular meetings were one of the key takeaways that I will also be implementing in my supervisory journey when collaborating with other colleagues.

Advantages

The advantages of having two supervisors included the rich perspectives, skillsets, and insights each brought to the doctoral journey. For instance, Professor Eunice, a biology specialist, provided valuable and critical feedback on the biology content, challenging my understanding and strengthening my subject matter knowledge. Her feedback often turned into meaning making opportunities for me as a biology lecturer and novice supervisor. On the other hand, Professor Marissa, whom I referred to as the 'editor', and 'tech-savvy' often took care of the language issues, layout issues, and overall coherence of the arguments. As an English Second Language speaker, I struggled with academic writing, which hindered my academic writing journey greatly. To assist me, Professor Marissa recommended several grammar editing tools that helped me refine my ideas and improve my overall grammar. The skill of using these editing tools (such as Grammarly, Quill Bolt, and many others) is effectively another valuable aspect that I will certainly pass on to my postgraduate students to aid their academic writing.

Collaborative Supervision and Mutual Learning

One valuable lesson I also learned is the importance of supervisors knowing each other's strengths and being willing to listen and learn from one another. Comments like, *"Eunice is actually good with aligning the title with the research questions...*", *"...I have actually learned a lot from Eunice about supervision, thank you Eunice...!",* "*...I didn't know as well…what does ontology, epistemology and axiology mean. I didn't know how to help the student..."* and "*Eunice is the guru when it comes to methodology..."* highlighted their mutual respect and collaborative learning. This dynamic made the feedback sessions more effective, with the expert supervisor leading and providing critical as well as valuable feedback. These interactions made me realise that my doctoral journey was not just about my learning, but we were all collaboratively learning from one another. These interactions were eye-opening and kept me going, thus in my journey as a novice supervisor I will forge positive relations with my colleagues for us to better support the student's journey and also sharpen my supervision skills in the process.

10.5. Limitations

Taking into consideration that this study is based on a relatively small sample that consisted of four biology lectures at a single university, the results of this study cannot be generalised to other teacher educators, students, departments, universities, or other contexts for that matter. The study also acknowledges that the analysis of qualitative data is somewhat inevitably influenced by the researcher's role, life experiences, and background. As earlier stated, the researcher is a former undergraduate student as SAX who was also taught by some of the participating teacher educators. Therefore, as argued by Denzin and Lincoln (2011) this aspect might have impacted the approach to the interpretation of the data compared with how others might approach the data and analysis. However, the analysis of this study involved colleagues who served as critical friends (a concept used in self-study methodologies) and participants to verify the accuracy of the transcripts of the lectures and interviews, coding processes

and to challenge my overall perspectives and interpretations. Once the data was analysed, a colleague who was familiar with the coding framework was also asked to verify the coding process as explained in Chapter 3 (sub-section 3.8.3). Furthermore, to strengthen the trustworthiness of the analysis, the findings are presented with quotes to support the interpretation. Despite these limitations, I believe that the findings of this study contribute to what is known and unknown about meaning making opportunities and how they manifest in biology lectures as the study tried to capture multiple perspectives of the teacher educators, teaching different biology topics to students at different levels of study within the same environment.

Another limitation of this study is that it mainly focused on the teacher educators meaning making activities and not the students holistically. While the study enabled me to skillfully infer the impact of meaning making opportunities on students' observable forms of engagement, it failed to capture the intricacies of their cognitive developments based on the manifesting meaning making opportunities in the various biology lectures. Consequently, while the study offered valuable insights into the teacher educators' experiences, perspectives, and challenges about the manifesting meaning making opportunities in their lectures, it leaves unanswered questions regarding the underlying cognitive processes driving the observed forms of engagements, behaviours, and overall academic performance.

10.6. Implications and Recommendation of this study

One of the key results of this study revealed that 'rich' meaning making opportunities are an amalgam of teacher educators' meticulous planning, subject matter knowledge, levels of creativity, and underlying teaching philosophies. This finding is significant given that Nyamupangedengu and Lelliott (2018) revealed that teacher educators in South Africa often receive little to no training or orientation when first employed in higher education institutions. Consequently, both the content they teach, and their pedagogical approaches are largely left to their discretion. To address this gap, this study proposes that new biology education staff could be supported through structured guidelines, such as those outlined in Table 10.1, which draws on the TSPCK framework for facilitating the creation of 'rich' meaning making opportunities during lectures.

These results further highlight the need for teacher educators to ground their practice in both disciplinary research (in Life Sciences) and the scholarship of teaching and learning (SoTL) (Kern et al., 2025). Disciplinary research equips educators with insights into common misconceptions and conceptual challenges in biology, while SoTL provides a lens for designing pedagogies that enhance student engagement and understanding (Kern et al., 2025). The DHET National Framework for Enhancing Academics as University Teachers (2018) explicitly reinforces this dual imperative: to renew curricula in line with disciplinary advances, and to strengthen pedagogy through continuous professional development, recognition, and teaching-focused communities of practice.

Thus, while this study is situated within biology education, its implications extend more broadly across higher education. It contributes to the national imperative of enhancing teaching and learning to improve student success, while also strengthening the preparation of future Life Sciences teachers. In this way, the findings affirm the relevance of research-informed pedagogy and the DHET framework in shaping sustainable, high-quality teaching practices in South African universities.

10.7. Directions for Future Studies

As earlier mentioned, the focus of this study was limited to the exploration of how meaning making opportunities manifested in biology lectures at SAX, the study believed that it was successful in documenting this knowledge as evidenced by students' observed forms of engagement. However, the study cannot fully account for whether these meaning making opportunities appeared to be successfully correlated with student's overall academic success as earlier stated. Therefore, future studies can explore the impact of the manifesting meaning making opportunities in other biology lectures about students' academic performance or success.

Other suggestions involve future studies:

- Conduct a longitudinal study to examine the long-term impact of meaning making opportunities on student learning and retention. Such studies can follow a cohort of students over an extended period to assess the effectiveness of different social exchanges in fostering lasting understanding resulting from various meaning making opportunities.
- Investigate how professional development programs can support educators in incorporating social exchanges into teaching, with specific attention to the role of language and multilingualism in shaping meaning making opportunities.
- Explore how various types of questions strengthen the 'richness' of the manifesting MMOs
- Explore the manifestation of MMOs in other STEM disciplines This would help identify transferable best practices and context-specific adaptations necessary for diverse educational settings.
- Foreground students' voices by examining their perceptions of MMO effectiveness and the socio-emotional dimensions of engagement, such as motivation, confidence, and identity development. Understanding how students experience and respond to MMOs would deepen theoretical models of meaning making and inform more learner-centered pedagogies.

All these future studies have the potential to contribute to an enhanced understanding of quality methodologies that can be implemented in biology classrooms to generate 'rich' meaning making opportunities that can develop conceptual understanding of abstract biology concepts, resulting in improved student participation and general academic performance.

10.8. Conclusion

This study was framed by the sociocultural theory which posited that learning happens in social contexts during interactions and is mediated by language and other cultural artefacts. Thus, the four social exchanges (talk, visual representations, gestures and/or feedback, and writing and/or drawing) were used in this study to document the type of meaning making opportunities that manifested and how they manifested in biology lectures in this study. The results of this qualitative multiple case study highlighted the multifaceted nature of meaning making opportunities manifesting in biology classrooms. The results further highlighted that there is an amalgam of factors that can strengthen the manifestation of meaning making opportunities in biology lectures. For example, the centrality of meticulous teacher planning, teacher educator Pedagogical Content Knowledge, the impact of teaching philosophies. This also includes specific constructivism in promoting collaborative and active environments for student engagements, and the need for creativity in the selection of suitable teaching and learning strategies in the manifestation of meaning making opportunities. The other factors involved the lecturer's knowledge of context, language-related issues and textbook-related misconceptions. These factors can all become hindrances when not carefully considered by the teacher educators in the planning phases of their lectures. The findings showed that addressing these challenges requires a holistic and integrated approach involving institutional support, professional development, and a commitment to creating a dynamic and inclusive learning environment among teacher educators in collaboration with their students. By acknowledging and proactively addressing these challenges, biology teacher educators can be in a better position to foster meaningful learning experiences for their students considering that the manifestation of meaning making opportunities is largely a collaborative process between the teacher educators and their students. Given that meaning making happens when the teacher educators and students engage in social interactions about the presented content.

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12. Appendices

Appendix 12.1: Transcripts of recorded lectures

Lecturers	Embedded lecture 1 and 2 transcripts
Appendix 12.1.A Dr Chris' Transcripts of recorded lectures	Chris coding 2022 final .docx
Appendix 12.1.B Dr Mollys' Transcripts of recorded lectures	Dr Molly coded transcripts 2022.docx
Appendix 12.1.C Dr Moses' Transcripts of recorded lectures	Moses Lecture transcripts .docx
Appendix 12.1.D Dr Ellen's Transcripts of recorded lectures	Dr Elle Transcript 2023.docx

Appendix 12.2: Recorded VSRI transcripts

Lecturers	Embedded lecture 1 and 2 transcripts
Appendix 12.1.A Dr Chris' VSRI Transcript	Dr Chris interview transcript.docx
Appendix 12.1.B Dr Mollys' VSRI Transcript	Dr Molly Interview transcript.docx
Appendix 12.1.C Dr Moses' VSRI Transcript	Dr Moses Interview transcript .docx
Appendix 12.1.D Dr Ellen's VSRI Transcript	Dr Ellen Interview final.docx

Appendix 12.3: Ethics clearance letter

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Xaba

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H19/07/38**
PROJECT TITLE	Investigating opportunities that biology lectures create to promote meaning making during instruction at a University
INVESTIGATOR(S)	Miss N Xaba
SCHOOL/DEPARTMENT	Education/
DATE CONSIDERED	19 July 2019
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	28 November 2022

DATE 29 November 2019 **CHAIRPERSON** (Professor J Knight)

cc: Supervisor : Prof M Rollnick and Dr E Nyamupangedengu

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we 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. **I agree to completion of a yearly progress report.**

Signature

19 / 07 / 2019
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix 12.4: Letter requesting for permission to do my study at SAX

RE: Request for permission to do my study at Wits School of Education

My name is Nomzamo Xaba, and I am a PhD student at the School of Education of the University of the Witwatersrand.

I am conducting research that is entitled: ***Investigating opportunities that biology lecturers create to promote meaning making during instruction at a university.***
This qualitative case study involves the invitation of four biology B.Ed. undergraduate biology lecturers. Each of the lecturers will be observed and videotaped teaching two different one-hour long sessions to their undergraduate students, in order to understand how they create opportunities for meaning making in their classrooms. The data received from the videotapes will be used to highlight the areas of interest that will be used as prompts for the Stimulated Video recall interviews. The same videos will also be used for conducting focus group interviews with the six selected students – two students from each of the three participating lecturers' venues. This study is interested in meaning making because, it is an intellectual process that allows individuals to interpret and organise knowledge in ways that are more understandable to them. Moreover, meaning making is important in any educational context as it offers students opportunities to gain an enriched understanding of the subject matter, which often goes beyond the memorisation of facts and definitions.

I hope you would not mind participating in this completely voluntary study that seeks to contribute to the knowledge development of undergraduate biology lecturers within higher learning institutions.

Please feel free to contact me if you have any questions.

Many thanks,
Nomzamo Xaba
1835 Firethorn Street, Lufhereng, Soweto
E: 588607@students.wits.ac.za
C: 0617947792

Appendix 12.5: Information sheet for the biology lecturers

Dear Lecturer,

My name is Nomzamo Xaba, and I am a PhD student at the School of Education of the University of the Witwatersrand.

I am doing research that is entitled: ***Investigating opportunities that biology lecturers create to promote meaning making during instruction at a university.*** My investigation involves the invitation of four biology B.Ed. undergraduate biology lecturers. Each of the lecturers will be observed and videotaped teaching two different one-hour long sessions to their undergraduate students, in order to understand how they create opportunities for meaning making in their classrooms. The data received from the videotapes will be used to highlight the areas of interest that will be used as prompts for the Stimulated Video recall interviews. The same videos will also be used for conducting focus group interviews with the twelve selected students – two students from each of the participating lecturers' venues. This study is interested in meaning making because, it is an intellectual process that allows individuals to interpret and organise knowledge in ways that are more understandable to them. Moreover, meaning making is important in any educational context as it offers students opportunities to gain an enriched understanding of the subject matter, which often goes beyond the memorisation of facts and definitions.

I hope you would agree to participate in this completely voluntary study that seeks to contribute to the knowledge development of undergraduate biology lecturers within higher learning institutions. I would really appreciate your assistance in allowing me to videotape, observe two of your lectures and interview you using a video Stimulated Recall technique, based on your two lectures. The interview sessions will be 45-50 minutes long. Please note that, this is not a test, it is not for marks, and it is voluntary, which means that you do it at your own free will. Also, if you decide halfway through that you prefer to stop, this is completely your choice and will not affect you negatively in any way.

I will not be using your own name, but I will make one up so no one can identify you. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely and destroyed between 3-5 years after I have completed my project.

I look forward to working with you! Please feel free to contact me if you have any questions.

Many thanks,

Nomzamo Xaba
1835 Firethorn Street, Lufhereng, Soweto
E: 588607@students.wits.ac.za
C: 0617947792

Appendix 12.6: Informed consent form for interviews

Wits School of Education

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3221 • Fax: +27 11 717-3009 • E-mail: enquiries@educ.wits.ac.za • Website: www.wits.ac.za

LECTURERS CONSENT FORM **November 2019**

Dear lecturer,

Please fill in the reply slip below if you agree to participate in my study called: ***Investigating opportunities that biology lecturers create to promote meaning making during instruction at a university***.

My name is: _____

Circle only one answer

Permission to review/collect documents/artefacts

I agree that a direct observation schedule can be used for this study only. **YES/NO**

Permission to observe you in class

I agree to be observed in class. **YES/NO**

Permission to be audiotaped

I agree to be audiotaped during the interview or observation lesson **YES/NO**

I know that the audiotapes will be used for this project only **YES/NO**

Permission to be videotaped

I agree to be videotaped in class. **YES/NO**

I know that the videotapes will be used for this project only. **YES/NO**

Permission to be interviewed

I would like to be interviewed for this study. **YES/NO**

I know that I can stop the interview at any time and don't have

to answer all the questions asked **YES/NO**

Most convenient time and date for interview to be conducted

Date (s): _____ **Time slot(s) _____**

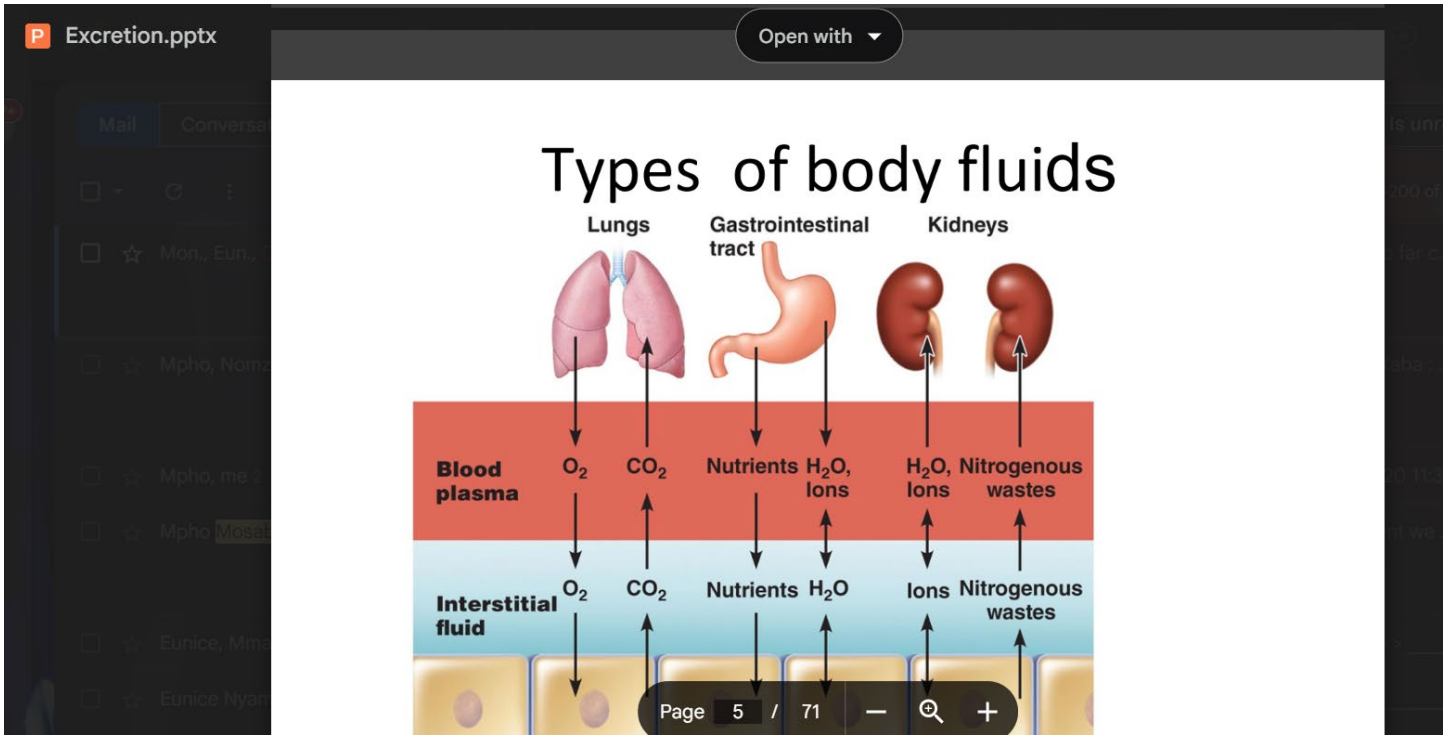
Informed Consent

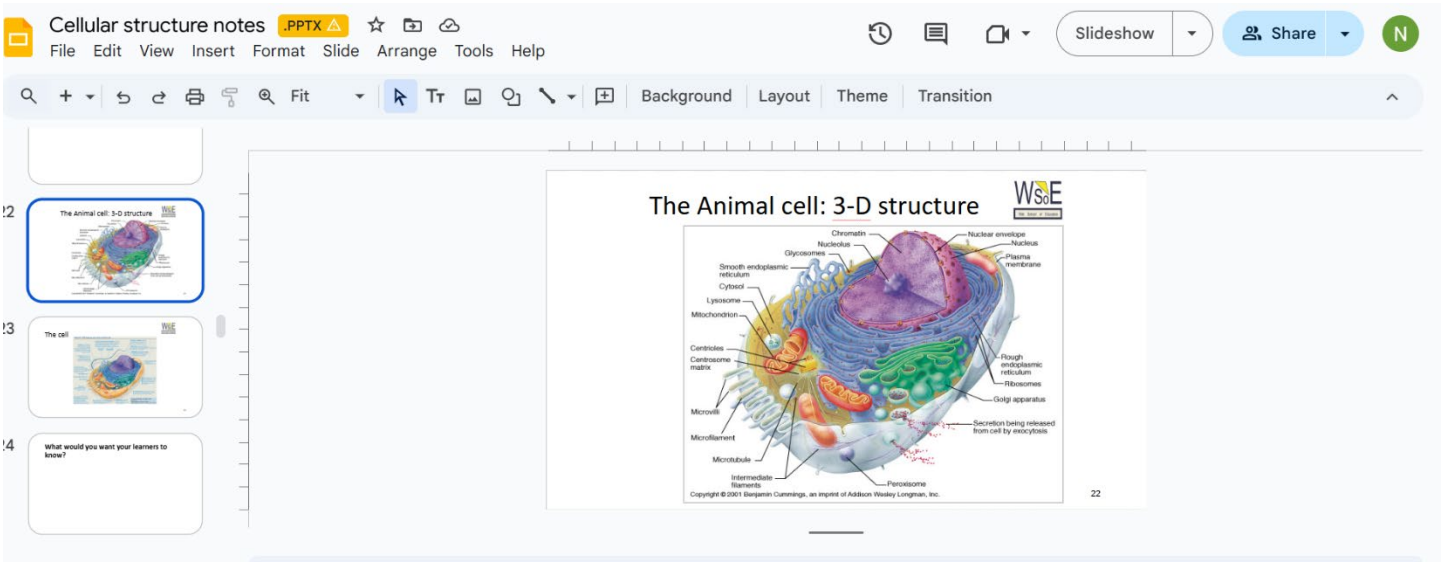
I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotape
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Signature_____ **Date_____**

Appendix 12.7: Examples of Collected PowerPoint Slides




Cellular structure notes
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Chromatin
Nucleolus
Glycosomes
Smooth endoplasmic reticulum
Cytosol
Lysosome
Mitochondrion
Centrioles
Centrosome matrix
Microvilli
Microfilament
Microtubule
Intermediate filaments
Peroxisome
Nuclear envelope
Nucleus
Plasma membrane
Rough endoplasmic reticulum
Ribosomes
Golgi apparatus
Secretion being released from cell by exocytosis
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The cell
What would you want your learners to know?