Comparing the effectiveness of hands-on dissections and ICT simulated virtual dissections in Grade 10 Life Sciences

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A research project submitted in fulfilment of the requirements for MDiss

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March 2025

Abstract

With the recent developments in the digital and ICT worlds as well as with regards to technology in general, life as we know has been significantly transformed. This is especially crucial to us as teachers in the educational world as we have witnessed the way in which teaching and learning takes place, which has been revolutionized. Due to the manner in which the integration of ICT tools has advanced pedagogical approaches, it is now a matter of urgency that we evaluate the methodologies that we employ. We are immersing ourselves in a technological and digital era, and as such, more and more research is being conducted on the implementation of ICT in the classroom.

This study used a mixed method approach to explore and compare the effectiveness of hands-on dissection and simulated dissections. This was done by conducting a hands-on dissection of a cow's heart and an ICT simulated dissection done virtually using an online simulator on smart devices. The study was based at a South African high school with Grade 10 Life Sciences (Biology) learners. The learners were taught the content on the topic of the mammalian heart and thereafter were asked to answer a pre-dissection test based on their theoretical content knowledge. The learners were then randomly split into two groups, where one group conducted a hands-on dissection of a cow heart while the other group conducted a simulated dissection of a cow heart using the previously mentioned online simulator on their smart devices. Both groups were then asked to write the post - dissection tests, which allowed me to observe the improvements in their understanding by comparing their answers from the pre - and post - dissection test and aligning them with the mode of dissection they partook in. In addition to the overall understanding that each dissection helped learners achieve, this study also aimed to observe the level of learner engagement and interaction with each mode of dissection (viz. Hands-on dissections and simulated dissections) in order to provide a more comprehensive picture of the learners cognitive and practical experience.

Finally, from these two groups, fifteen learners volunteered to answer a questionnaire based on their experiences using both modes of dissection. The pre-dissection test and post dissection tests, as well as the questionnaire, allowed me to observe how the different dissections increased the depth of their knowledge as well as how they

experienced each mode of dissection, thus providing me with a holistic evaluation of the effectiveness of both modes of dissection, which took into consideration factors such as engagement, understanding, confidence and enjoyment and other factors.

This research explored the effectiveness of hands-on dissections in comparison to simulated dissections. From the trends that I was able to observe and the patterns that I have taken note of; I found that both modes of dissection offer their own educational benefits and also have their own limitations. There was evidence of improvement in understanding on the part of the learners, which is clearly visible in the pre - and post - dissection tests. There were also other factors, such as the interest and preferences of learners, which played a role in the overall effectiveness of each mode of dissection. Hands-on dissection allowed learners to physically interact with the anatomy, enhancing their understanding through direct experience. In contrast, virtual dissection provided a structured, repeatable environment that facilitated deeper theoretical learning. The factors surrounding each mode of dissection has been further explained in the study.

Neither method, however, was able to fully address all aspects of learning when used on its own, and as such, it would be unfair to only look at some factors. As a result, my recommended stance is that a hybrid mode of dissection would be the most effective. A hybrid model aligns with other *pedagogical research promotes a blended learning approach in order to appeal to different learning styles and methodologies; this method combines conceptual and experiential understanding.* This blended approach leverages the strengths of each method, allowing learners to explore the heart in multiple ways and benefit from the advantages that each mode offers.

On a larger scale, in Life Sciences as a subject, I recommend that we treat each case individually, as a hybrid mode of dissection may not always be the most effective. For example, a DNA extraction may be more effective when done using a simulation, while the dissection of the kidney may be more effective when done using a hands-on dissection. Furthermore, it may not be possible to conduct one of the modes of dissection, for example, in the case of not having the equipment and resources for either mode of dissection.

In some cases, it may be more beneficial to use a hybrid model within one topic, for example my study suggests that when teaching the mammalian heart teachers should begin with the simulation of the heart to teach the appropriate structures then, teach the theoretical lesson, which can be followed by the hands-on dissection and finally be reinforced by looking back to the simulation.

Keywords: Hands-on dissections, ICT-simulated dissections, Life Sciences, hybrid model

Acknowledgements

First and foremost, I would like to thank the almighty God. He has given me strength and guidance throughout all the challenging moments of completing this dissertation.

I am eternally grateful to my supervisor, Dr. Portia Mabenge for her guidance throughout the research process without who's assistance, this research would not have been possible.

I would like to thank the University of Witwatersrand for the opportunity to study and research under their institution.

And finally, to my family for their unwavering support during my studies and in all the fortes of my life.

<u>Plagiarism Declaration</u>

I <u>Ayesha Ismail</u> declare that this research report is my own unaided work except where otherwise acknowledged. It is submitted for the degree of Master of Education at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other University.

Date: 17 March 2025

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Contents

List of Tables

List of Figures

Definition of terms

- For the purpose of this study, I have used the following terminology:

- ICT - Information and communication technology.

- Simulations: the production of a computer model of a situation or process for the purpose of study.

- Meaning making - the process by which people interpret situations, events, objects, or discourses.

- Experiments: the performance of a scientific procedure to determine an outcome.

- Practicals - these are activities that engage learners, helping them to develop important skills, understand the process of scientific investigation, and develop a broad understanding of scientific concepts.

- Dissections: The process of cutting apart or separating tissue, such as in the study of anatomy or during a surgical procedure.

- Simulations dissection - the production of a computer model of a dissection for the purpose of study.

- Hands-on dissection - a dissection using real-life equipment, organs (of an animal), etc.

- Live specimen - specimens obtained from living organisms.

- Both methods of dissection - simulations of dissections and hands-on dissections.

- Both modes of dissection - simulations of dissections and hands-on dissections.

- Pre-test – Pre-dissection test - written after the content was covered but before the dissections and will serve as the baseline for comparing how the dissections affected learners' understanding.

- Post-test - Post-dissection test - this test was written after the dissections and will be compared to the pretest that was previously written.

- The theoretical lesson- focused on the heart, required the learners to complete the pre-dissection test.

Chapter 1: Introduction

1.0 Introduction

This chapter acts as an overview of my study, in which I have outlined the context of the study as well as the rationale and significance of comparing the effectiveness and outcomes of traditional hands-on dissections and ICT simulated dissections. The chapter also talks about the research questions and objectives, which shows how important it is to think about the learners' understanding, skill development, and engagement. It also talks about the pros and cons of each mode of dissection and the possible benefits of a hybrid model that combines the two.

The significance of the study also focuses on the importance of different dissections within the curriculum for advances in Life Sciences education.

1.1 Background

The era we are currently living in is characterized by advancements and change. Information and Communication Technology (ICT) is revolutionizing the already dynamic education system in this era. We are now delving further into the digital realm (Livari, Sharma and Ventä-Olkkonen, 2020). With the way the world continues to become more digitized and the integration of ICT in different sectors, the education system has room for exponential growth; this shift is not simply following a *trend but rather is an essential shift that reflects the evolving nature of global society (Bawden and Robinson, 2020;* Rubio and Guevara, 2019; Lawrence and Tar, 2018).

As of late, the education system has taken major strides into the digital world; this was further expedited by the occurrence of the coronavirus and the pandemic-related lockdowns that were enforced in order to prevent the spread of the virus, which led to mainstream education being forced to conduct remote learning (Coman, Tîru, Mesesan-Schmidt, Stanciu and Bularca, 2020). Finding the best way to use ICT tools and teaching methods (Toma et al., 2023) led to a lot of new opportunities in the education system, which was the initial challenge. However, despite the newfound opportunities provided by ICT tools, the pandemic's emergency learning has changed the perspectives of both learners and teachers regarding the general use of ICT (Oliveira et al., 2021).

However, ICT can be implemented in the classroom at different levels. There is also a more advanced level where ICT can be used. For example, it can be used to show simulated experiments and dissections, among other things (El Janous et al., 2022). Taking this context into consideration, my current study focuses on the digitalization of the education system. Specifically, my goal was to investigate the application of ICT-simulated dissections in Life Sciences education. This comparative study assesses the differences between hands-on dissections and simulated dissections. I focused on how well each method of dissection works by watching how well learners understood when they did a simulated dissection and then comparing their results to those of learners who did a real dissection. This comparative analysis aimed to determine the opportunities and limitations of each mode of dissection. Finally establishing how the preferences and enjoyment of participants in each mode of dissection relate to learners' understanding. By addressing these components, I was able to compare the overall effectiveness of hands-on dissections and ICT simulated dissections.

<u>Overview of learning outcomes from the mammalian heart in the South African curriculum and educational goals of heart dissections.</u>

With regards to the South African Life Sciences curriculum, the topic of the mammalian heart is integral to understanding the human body, it is focused within the grade 10 curriculum in the Further Education and Training (FET) phase.

The topic of the mammalian heart falls under the strand of grade 10 Life Sciences: "Life Processes in plants and animals " under "Transport Systems in Animals," and is primarily concerned with the anatomy and physiology of the heart, the cardiac cycle and circulation within the body (Department of Basic Education, 2011).

The learning outcomes that are related to the mammalian heart are summarised below

- Identification and description of the structure of the mammalian heart (such as chambers, valves etc).
- Explanation of the cardiac cycle, blood flow through the heart, as well as systemic and pulmonary circulation.
- Understanding of blood flow pathways.

- Discussion of common cardiovascular diseases, their risk factors, and preventive measures (Department of Basic Education, 2011).

When conducting a heart-dissection, in the past it was primarily conducted hands-on and the goal was to provide learners with an understanding of cardiovascular structures and functions. The hands-on approach intends to enhance biological knowledge of anatomical structures, which also in turn develops skills such as those used on laboratories and critical thinking, which spark interest in the Life Sciences (Kaiser et al., 2023).

It aimed to provide learners with a deeper understanding of the structure and related function of the heart. Learners are able to take note of the differences in size texture, and coloration, of the heart when comparing real specimens to textbook diagrams, this in turn reinforces the biological complexity of the heart (Kaiser et al., 2023). This hands-on approach strengthens memory retention and comprehension, as learners can physically locate structures such as the atria, ventricles, valves, and major blood vessels (Kaiser et al., 2023).

1.3 Problem Statement

In recent years there have been great advancements in the way in which we teach; it is therefore vital that teachers are equipped with all the necessary information to make decisions to ensure that the most suitable approach is used when teaching a topic.

In 2020, the world found itself facing an expedited leap into the digital era (Livari, Sharma, and Ventä-Olkkonen, 2020). This shift has impacted the manner and mode that teachers use to conduct their lessons, practicals, demonstrations, and simulations and how they engage with their learners. The domino effect of this is that it in turn impacts academic performance and the overall understanding of the topic itself. It further impacted the perception of both teachers and learners on what ICT education entails. However, the uses of ICT are far beyond using a smartboard to display a PowerPoint presentation or conducting an online quiz.

In light of this, my study was focused on how ICT simulations have the potential to revolutionize how we, as teachers, conduct our dissections, but it is of utmost importance that teachers are adequately equipped to make decisions on when it is more valuable to utilize an ICT simulated dissection and when it is more valuable to use a hands-on dissection, and in turn, we must consider the use of ICT in a manner that does not discard the traditional ways of conducting dissections.

The education system now finds itself in the unique position to utilize a hybrid model to reassess the limitations and opportunities of ICT (Cahapay, 2020). The main point of this study was to compare ICT (specifically ICT simulated dissections) to hands-on dissection in Life Sciences education. I have referred to a specific example when teaching the anatomical structure of the heart and letting learners dissect the heart.

Numerous studies have observed these advancements on both a basic and non-instructional level. There are also a lot of studies that look at the more advanced role of ICT in the classroom. Other researchers have written about how learners and teachers felt about using ICT in the classroom, but my study was more focused on a specific aspect of ICT in the classroom (Schmid et al., 2022). It specifically dealt with the implications of digitalized ICT simulations of dissection in comparison to traditional hands-on dissections. There are also numerous articles addressing ICT in general, but there are a lesser number of studies that deal with the issues of experimentation using ICT and even fewer assessing simulations of dissections using ICT, as it is relatively new and somewhat novel in developing countries such as South Africa. In conjunction with the opinions and experiences of learners and their overall grasp of the content, I have also compared the marks achieved by learners when they conducted the hands-on dissection and when they conducted the simulated dissection. I observed the trends shown in the way each learner answered each question and the explicit improvements of each answer that the learners provided (Luhamya, Bakkabulindi and Muyinda, 2021).

As the educational sector continues to evolve, the pedagogy and manner of teaching that a teacher employs require close attention; this is especially true when looking at the implications of integrating ICT into traditional teaching practices. ICT shows great potential, particularly with regard to learner engagement and collaborative and supportive learning styles (Hwang, Wu, and Chen, 2020). However, it also comes with the needs of teaching competency (Palloff and Pratt, 2019), development, as well as extensive planning and equipment. A clear understanding of how technology can enhance practical experiences, such as dissections, is essential for teachers to provide meaningful learning opportunities for their learners (Palloff and Pratt, 2019).

1.4 Rationale of the Study

With the ever-changing evolutionary advancement in technology, particularly in the last few years, it is essential for teachers to be able to employ ICT in meaningful ways, and it is therefore be of utmost importance for teachers to have access to information that will equip them to make decisions in their classrooms, specifically decisions regarding the use and manner in which they use tools such as ICT devices, simulations, smartboards, etc. It is possible to improve teaching and learning and the education system by using ICT in many ways, but only if teachers make informed and effective decisions. Technology and ICT in general can be a major aid, but it can also act as a hindrance to the learning process; this is entirely based on the way it is used. The choices made by teachers in their classrooms have a direct relation to the learning outcomes achieved. Overall understanding of concepts and marks on standardized tests show the effectiveness of the pedagogy. By providing teacher with access to the adequate information about the tools that are available, they will then be able to make decisions about the use of these tools, with ease and on a case-by-case basis, depending on the content being taught and the context of the classroom. In order to use ICT in the most effective manner as possible, it is necessary for the teachers to have a strong understanding of the concept (Jen et al., 2016). The findings of this study has equips teachers with more information on the ways in which ICT-simulated dissections influence learning/understanding and the ways in which hands-on dissections affordances are presented. On a larger scale, I hope this research aids the integration of ICT into every classroom on a day-to-day basis and help teachers create a classroom that is the most conducive to teaching and learning, thus improving the standard of education in South Africa as a whole. However, on a more personal level, this study helps individual teachers, including myself, find the best possible way in which to conduct dissections in their classrooms and how best to utilize the tools they are given; it is a point of personal growth and reflection for individual teachers such as myself.

1.5 Purpose of the study

The purpose of my study was to explore the effectiveness of hands-on and simulated dissections in grade 10 Life Sciences. Specifically, the study aimed to examine and compare the advantages and limitations of each method of dissection in order and to determine its impact on learners understanding of the mammalian heart. To achieve this, I compared the answers that learners provided in a pre-dissection test to those they provided in a post-dissection test to see the improvements and development in the answers that the learners provided.

1.6 Research aims and objectives

The purpose of this study was to determine the extent to which ICT dissections conducted through simulations and hands-on dissections influence the understanding of the mammalian heart by Grade 10 learners.

- To find out the extent to which ICT dissections conducted through simulations influenced the understanding of the mammalian heart by Grade 10 learners.

- To find out the extent to which traditional hands-on dissections influenced the understanding of the mammalian heart by Grade 10 learners.

- To identify the challenges and opportunities of the use of ICT based simulations and those of traditional hands-on dissections in Grade 10 Life Sciences.

- To better understand the views of learners with regards to the effectiveness of ICT simulated dissections in comparison with hands-on dissection in Life Sciences education at a Grade 10.

1.6.1 Research questions

Main Research Question

How did the effectiveness of ICT-simulated dissections compare with that of traditional hands-on dissections in Grade 10 Life Sciences?

Research Sub-questions

1. To what extent does ICT dissections conducted through simulations influence the understanding of the mammalian heart by Grade 10 learners?

2. To what extent does traditional hands-on dissections influence the understanding of the mammalian heart by Grade 10 learners?

3. What are the challenges and opportunities of the use of ICT-based simulations and traditional hands-on dissections in Grade 10 Life Sciences?

4. What are the views of learners with regards to the effectiveness of ICT simulated dissections in comparison with hands-on dissection in Life Sciences education at a Grade 10?

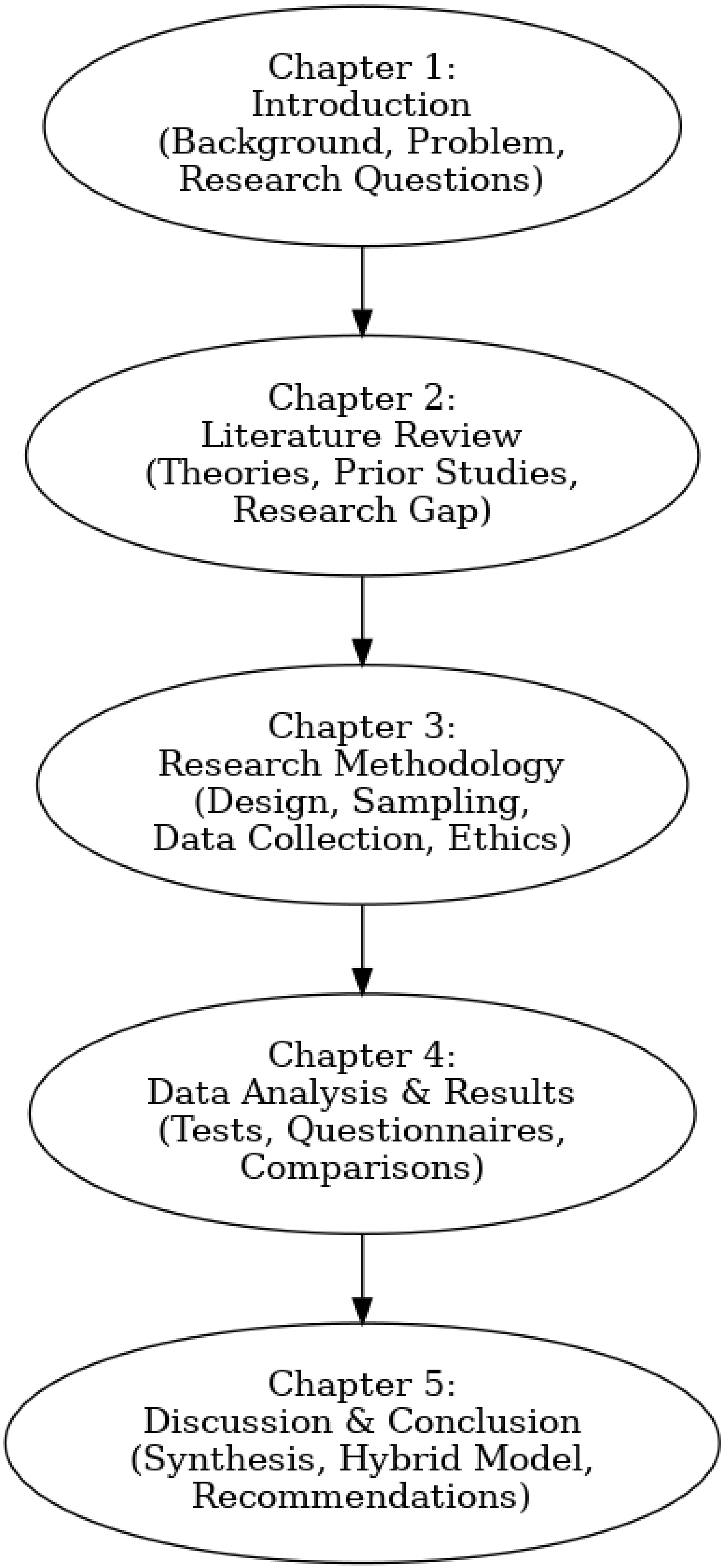
1.7 Chapter Summary

This study examined two types of dissections: hands-on dissections and ICT-based simulated dissections. These are used in Life Sciences classes for 10th graders, and the hearts of mammals are the main topic. The comparison of hands-on and ICT simulated dissections assess the effectiveness of both modes of dissection, this assessment noted the understanding, engagement, and performance of the learners.

The use of either method of dissection must be integrated into the curriculum properly, in order to improve learning outcomes, but if not, it can be ineffective or even detrimental to the understanding of learners. This study aimed to ascertain the strengths and limitations of both method of dissection such that teachers are provided with the knowledge to make informed decisions in their teaching practices that create the best possible learning outcomes.

Digital literacy is of great importance for the implementation of ICT simulated dissections. If teachers do not know how to appropriately utilize their resources, the use of it may cause more of a hindrance to the learning process. Therefore, it is vital for teachers to have access to enough information around available teaching tools so that they are able to effectively integrate them into their lessons. This research also examined the challenges that both learners and teachers face when adopting ICT simulated dissections in comparison to hands-on dissections as well as their individual perspectives, particularly in our context in South Africa, where there may be limited access to technology or other resources. Through this comparative analysis, the study aimed to contribute to the improvement of the quality-of-Life Sciences education by promoting a hybrid approach that balances traditional and digital learning methods.

1.8 Research report overview



Chapter 1: Introduction

The first chapter introduces the study by providing the background and context in which my research was situated. It explained the problem statement, outlined the rationale and purpose, and set out the aims and objectives. The key terms were defined, and both the main and sub-research questions were highlighted. This chapter also pointed to the increasing role of ICT in South African classrooms and positioned the investigation within Grade 10 Life Sciences, specifically around how learners understand the mammalian heart when exposed to hands-on dissections compared to ICT-simulated dissections. The chapter ended by stressing the significance of the study, with reference to the possible benefits of a hybrid dissection model.

Chapter 2: Literature Review

This chapter engaged with existing literature in order to explore the two methods of dissection in both local and international contexts. It discussed historical perspectives, policy guidelines, ethical considerations, and practical benefits linked to teaching dissections. Learner engagement, memory retention, and psychological factors were considered, alongside challenges such as resource constraints, cultural sensitivities, and unequal access to technology. The theoretical framework is built through Constructivist Learning Theory, Experiential Learning Theory, Cognitive Load Theory, and the TPACK model, which help to situate the study. The chapter concluded by pointing out the lack of comparative research between hands-on and ICT-simulated dissections in South African schools, highlighting the gap this study seeks to address.

Chapter 3: Research Methodology

In this chapter the research design is explained, with a focus on the mixed-methods approach that combines both qualitative and quantitative strategies. The target population was outlined, and the sampling method and procedures are described. Data collection tools included pre- and post-tests and a questionnaire, while the approach to data analysis was also explained. Ethical considerations and limitations were acknowledged. The overall aim of this methodology was to evaluate learner understanding, attitudes, and preferences towards the two modes of dissection.

Chapter 4: Data Analysis, Presentation and Interpretation

The fourth chapter presented and interpreted the findings. Results from the pre- and post-tests were compared in order to measure changes in learner understanding, while the questionnaire was used to capture learners' views and experiences. The analysis revealed that both approaches contribute to improved understanding, but in different ways. Hands-on dissections strengthen tactile and sensory learning, while ICT simulations provide opportunities for repetition and visualisation. Diversity in learner preferences is emphasised, showing that no single method worked best for all learners. The chapter also highlighted the challenges and advantages observed in both modes.

Chapter 5: Discussion, Recommendations and Conclusion

The final chapter uses the findings and discusses in relation to the research questions and theoretical framework to draw conclusions. Themes such as the effectiveness of ICT simulations, the role of hands-on experiences, and areas of overlap between the two were addressed. Learner perceptions played an important role in shaping the discussion. The chapter recommended that teachers use a hybrid approach, combining hands-on and simulated dissections to make the most of their respective strengths. Broader recommendations were also made for integrating ICT into Life Sciences, while recognising resource and training constraints. The study's contribution was acknowledged, along with its limitations, and directions for future research are proposed, such as expanding to other anatomical topics and larger learner groups.

Chapter 2: Literature Review

2.0 Introduction

In this chapter I review existing literature that covers the use of ICT and, more specifically, ICT-simulated dissections and experimentation, as well as hands-on dissections and experimentation. It looks at the theoretical benefits and challenges that other researchers have identified for both hands-on and ICT-simulated dissections. It then explores the theoretical framework that this study falls under. Lastly, it looks at the growing use of hybrid models for dissections that combine real dissections with simulated ones, as well as previous research on these types of learning methods.

2.1 Context of dissections in education

2.1.1 What are hands-on dissections and the South African context

Hands-on dissections have been an essential part of biology and anatomy education. Traditional hands-on dissections entail dissection and manipulation of the actual organ usually from an animal such as a cow or sheep, this mode of dissection allows for direct engagement with biological structures, providing a sensory and tactile experience to foster a deeper understanding of the anatomical structure being taught (Brown et al., 2023; Ghosh, 2016).

In a South African context, dissections form part of the Life Sciences curriculum prescribed by the Curriculum and Assessment Policy Statement (CAPS), at grade 10 level this deals with the structure and functions of the mammalian heart (Department of Basic Education, 2011), through practical exposure allowing learners to strengthen their understanding of the concept (Brown et al., 2023; Ghosh, 2016).2.1.2 What are

2.1.2 ICT simulated dissections and the South African context

Information and communication technologies (ICT) simulated dissections refer to computer-based or digital representation of biological dissections through digital software, 3D animations and other virtual models to supplement traditional hands-on dissections (Bogomolova et al., 2019; Wilson et al., 2017). These digital tools replicate the structures of the organ being studied in a controlled, interactive environment, it also allows learners to observe the function of the biological structure in action (Bogomolova et al.).

The recent rapid advancement of ICT had reshaped pedagogical teaching practices worldwide, this is also evident in the South African context, where the Department of Basic Education has encouraged the integration of digital tools in order to enhance curriculum delivery (Department of Basic Education, 2011).

2.1.3 Historical perspective on dissections in education

The use of dissections in a general context date back centuries in the education system; examples of this are evident in ancient civilizations in Greece and Egypt, etc., the earliest of which we know were conducted by the likes of Herophilos and Erasistratus in the third century BC. They explored human anatomy through cadaveric studies (Jeyakumar et al., 2019c). In Europe in the past, an increase in the number of medical universities led to an increase in human and animal dissections, this became an integral part of teaching anatomy (Ghosh, 2016). In later years dissections became more common until it became standard practice in Life Sciences education, (Ghosh, 2016).

More recently, there has been an increase in mindfulness of ethical issues when using animal specimens, this has left hands-on dissections under great scrutiny. As a result, alternative methods like ICT-simulated dissections are becoming more popular. This is a big change in the way we teach because it balances scientific inquiry with ethical concerns (Kurt et al., 2020).

2.1.4 National (South African) and International Policies on Animal Dissections

Hands-on dissection requires the use of animal organs and, as such, is subject to national and international policies in order to find a balance between ethical issues and scientific inquiry methods. In the South African context, the policies relating to dissections align with ethical guidelines for animal use in education and research. If teachers are familiar with the policies that have been outlined, they are in a better position to navigate the ethical, legal, and pedagogical elements of dissections.

Together the Department of Basic Education (DBE) and the Department of Agriculture, Forestry, and Fisheries (DAFF) have formulated guidelines on the ethical treatment of animals for educational purposes. In the Life Sciences Curriculum and Assessment Policy Statement (CAPS), dissections are not compulsory; however, they are used often in order to improve learners understanding of anatomical structures and functions (Department of Basic Education, 2011). It is therefore important for schools that opt to conduct hands-on dissections to adhere to the stipulated ethical guidelines.

The South African National Standard (SANS) 10386:2008 provides the following ethical guidelines that are generally applicable for scientific research, but they can also be used by schools and universities to conduct dissections. The principles of replacement, reduction, and refinement promote the use of alternatives where possible (Zemanova, 2022). On a global level these principles also align international efforts to reduce animal use without negatively impacting the learning experiences.

The National Council of Societies for the Prevention of Cruelty to Animals (NSPCA) has advocated for stricter regulations on dissections in schools, the organization therefore greatly supports the use of simulated dissections. They also strongly suggest that learners should be given a choice to not conduct dissections if they have ethical or religious objections (Kavai et al., 2017). It is for this reason that some South African schools have added or substituted in ICT-simulated dissections as an alternative Hu et al., 2021).

2.2 Roles of dissections

2.2.1 The Role of Dissections in Developing Ethical Reasoning and Scientific Integrity

Both modes of dissection offer the opportunity to cultivate ethical reasoning among learners. One of the first elements to consider is the topic of the responsible use of animals in science; the sustainability of using it; and the overall treatment of living organisms (Zemanova, 2022). This in turn fosters a deeper appreciation for scientific integrity and responsibility among learners. Teachers can also integrate discussions on ethical concerns when conducting dissections, this encourages learners to critically evaluate the moral implications of dissections (Kavai et al., 2017).

2.2.2 The role of dissections in Inquiry based learning

This educational approach focuses on the learners' curiosity and need for active exploration within dissections; it is centred around encouraging learners to ask questions in order to build hypotheses and to analyse their findings through direct engagement with biological specimens (DeFeo et al., 2020). Traditional dissections align well with this educational approach.

With regards to ICT-simulated dissections: The tactile aspects of hands-on dissections cannot be replicated by this interactive tool. However, research has shown that ICT-simulated dissections can also help with inquiry-based learning if they are set up correctly. This is achieved by using learners' problem-solving skills and simulating real-life scientific exploration (De Jong et al., 2021). Combining virtual tools with hands-on experiments can enhance learners' critical thinking and deepen their understanding of anatomical functions (De Jong et al., 2021).

2.2.3 The role of dissections in developing problem-solving skills

Scientific inquiry is a corner stone of Life Sciences education, and dissections offer this element of learning by promoting problem-solving abilities among learners. When conducting dissections, learners are required to observe, hypothesize, analyse, and draw conclusions (Jeyakumar et al., 2019). In particular, hands-on dissections promote adaptive thinking by allowing learners to navigate challenges like identifying anatomical structures and building on the findings of their exploration (Zumwalt et al., 2022). It has been seen in research by Hu et al. (2021) that when learners exposed to dissection-based learning they tend to perform better as it stimulates in critical thinking assessments; compared to those who engage only in textbook-based learning (Hu et al., 2021). Simulated dissections also contribute to problem-solving skills by incorporating interactive scenarios and quizzes that require learners to apply their knowledge dynamically (Kurt et al., 2020).

2.2.4 The role of dissections in Learner retention and memory recall

In order to deem learning as effective learners must be able to retention the knowledge, studies have indicated that active participation in dissections enhances learners' ability to recall information on a long-term basis. Further it has been found that learners who physically manipulate specimens are more likely to remember structural details in comparison to learners who only engaged with passive learning materials (Reedy, 2015). This can be attributed to the fact that hands-on dissections provide multisensory experience by providing one or more of the following: visual, tactile, and/ or kinaesthetic learning, this improves neural connections as well as memory encoding (Meijer et al., 2019). In the case of simulated dissections, these dissections have been noted to help learners remember and recall information by allowing them to see the same anatomical structures repeatedly. Which means that learners are able to revisit the material more than once (Lazarinis et al., 2020). A hybrid model which using both hands-on and simulated methods together is the best way to tab into memory recall and concept retention (Bogomolova et al., 2019).

2.2.5 The effectiveness of peer-led learning in dissections

Peer-led learning has been recognized as an effective instructional strategy in the education system but it is also very valuable in biological education. Learners collaborate and work together when conducting dissections, this brings about effective learning. Often dissections are conducted by groups of learners together where they can share observations, discuss findings, and explain concepts to one another. These interactions between peers reinforces their own understandings as well as those of the other learners. Mishra and Koehler (2020) suggest that peer discussions while conducting dissections improve learners' comprehension and retention, as they are able to articulate and defend their interpretations of the topic (Mishra and Koehler, 2020). It also promotes a sense of teamwork and communication skills, which are valuable for future careers in science and healthcare (MacPherson and Lisk, 2022).

2.3 Hands-on dissections

2.3.1 The importance of hands-on dissections in Life Sciences education

In Life Sciences classes, dissections let learners interact with the body parts they are studying. They can put the ideas they are learning about in the classroom into practice by seeing how complex and linked organs and tissues are (Jeyakumar et al., 2019). Another added advantage of hands-on dissections is that it helps learners create their spatial awareness and fine motor skills (Bogomolova et al., 2019).

Dissections are tactile interactions, and as such, they enhance the cognitive retention of the learners, as they are now able to visualize and comprehend anatomical relationships rather than theoretical or simulated learning (Bogomolova et al., 2019). Also, dissections help kids learn important scientific skills like how to observe and come up with hypotheses, as well as how to think critically about biological processes (Jeyakumar et al., 2019b). As hands-on dissections are an active process, it fosters the development of scientific reasoning. In instances studied by Zumwalt et al. (2022), learners who engage in dissections are more likely to demonstrate improved critical thinking abilities and problem-solving skills (Zumwalt et al., 2022).

According to Kaiser et al. (2023), hands-on methods of dissection have continued to play a significant role in Life Sciences education because the tactile style of learning helps learners appreciate the structure of life. This is a real-life experience that simulates their senses. These kinds of dissections often include the use of natural specimens showing actual anatomical features. By handling tissues and organs physically, learners develop skills such as how and where to actually cut, understanding space, and identifying anatomy. In contrast, Dauer and Dauer (2016) state that hands-on dissections give a more appreciative attitude and perspective toward biological complexity. However, Thisgaard and Makransky (2017) say that the sensory feedback that comes from touching and manipulating tissues directly helps to solidify theoretical ideas and encourages a deeper comprehension of how living things work and how they are connected.

When looking at hands-on dissections, learners are not only equipped with improved cognitive and motor skills; hands-on dissections also promote engagement and curiosity, making the lesson more interactive and immersive.

Because the learners were able to physically explore the structures, they are able to find a greater appreciation for biological complexity, in turn making them more interested in the subject (Lazarus et al., 2020).

Hands-on dissections also promote sensory and emotional engagement; learners emotional intelligence and ethical reasoning come into play (Ghosh, 2017).

This way of dissecting supports an inclusive approach to education because it works for different types of learners, especially kinaesthetic learners who learn best when they can physically interact with learning materials instead of just using hearing or sight (Kulkarni et al., 2021).

2.3.2 The impact of hands-on dissections on learner engagement.

Hands-on learning promotes greater engagement among learners when compared to passive learning (Bogomolova et al., 2019). These dissections have tangible connection between theoretical knowledge and the real world. This results in an increased motivation and enthusiasm for the subject matter amongst learners (Jeyakumar et al., 2019). It has also been seen that learners who actively engage in dissections have increased interest in biological sciences and as a result are far more likely to pursue careers in medicine or research (MacPherson and Lisk, 2022). On the other side of this argument participation of learners may vary, this particularly true in cases where learners experiencing discomfort when working with animal specimens (Zumwalt et al., 2022).

2.3.3 The role of hands-on dissections in developing practical laboratory skills

Life Sciences education promotes the development of practical laboratory skills, this is increasingly valuable for learners that are interested in careers in Health care fields, (Kaiser et al., 2023). This form of dissections allows learners to develop precision, dexterity, while all in all creating an understanding of the structures being taught (Bogomolova et al., 2019). Elements such as handling surgical instruments, making accurate incisions, and understanding tissue consistency cannot be recreated by simulated dissections (Dauer and Dauer, 2016). Therefore, learners who solely rely on simulated dissections may face difficulties transitioning to real-world laboratory work as they do not have the experience of working with physical structures (George et al., 2022).

2.3.4 The impact of hands-on dissections on learner confidence in scientific skills

In order to conduct hands-on dissections with ease, learners should be familiar and comfortable, this means that they require confidence in laboratory settings, this is of even more importance for learners pursuing scientific careers. Engaging with real specimens encourages learners to develop hands-on laboratory skills, which in turn boosts their confidence in conducting biological experiments (Kaiser et al., 2023).

Simulated dissections cannot always recreate real life experience and may not be able to produce the same level of technical competency (George et al., 2022). A hybrid model is suggested where learners first do simulated dissections then hands-on dissections in order to boost learner confidence (Kurt et al., 2020).

2.3.5 Challenges and limitations of hands-on dissections

One of the most significant logistical limitations of hands-on dissections is the availability of specimens, classroom space, equipment, etc. (Wilson et al., 2017). In addition to the above, time constraints are a challenge since the syllabi do not always allocate adequate time for the dissections (Wilson et al., 2017).

Another problem that many schools have, according to Jorquera and Vogel (2021), is that they don't have enough money. The costs of buying, storing, and getting rid of specimens can be draining on school budgets, so much so that hands-on dissections are often left out of the regular curriculum (Zemanova, 2022).

The ethical question of cruelty to animals is also raised by hands-on dissection. Dissections conducted in schools are often seen as cruelty to animals, done under the guise of education; it contributes to the death of animals. When an investigation was conducted, it was found that the suppliers of these organs/animals drown the cats in burlap sacks, inject rats with embalming fluid, and keep frogs for weeks without food (Kline, 1995; Zemanova, 2022).

A challenge associated with hands-on dissections that I will address later in the literature review is that of the psychological discomfort and emotional distress that comes with handling animal specimens (Lai et al., 2023b).

Some societies argue that the animal organs that are used could be used as a source of food because there is a global food shortage (Zemanova, 2022). Some religions have laws against using animals in this way (Kline, 1995; Zemanova, 2022).

While some researchers have indicated that hands-on dissections increase emotional awareness and intelligence (Ghosh, 2017), others argue that hands-on dissections can sometimes lead to the numbness to the value of animal life; it devalues the importance of the living creature and makes it seem disposable. Some religions have laws against using animals in this way (Kline, 1995; Zemanova, 2022).

2.3.6 The Impact of School Resources on Hands-on Dissection Quality

Hands-on dissection in Life Sciences education require the availability and distribution of resources, these factors have a great impact on the quality of the dissection. Hands-on dissections allow learner to directly manipulate and physically engage with the specimen, but this requires adequate access to the necessary resources, such as specimens, laboratory facilities, and dissection tools.

There has to be access to certain resources. The foremost of which is the availability of fresh or preserved specimens that are of a high quality is essential for the dissection to occur. Secondly, dissections require instrumentation such as scalpels, cutting boards, and probes, as well as safety equipment such as goggles and gloves. And finally, the dissection also has to take place in a safe and clean area, specifically in a laboratory space (Wilson et al., 2017).

One of the elements that limits the availability of resources is financial constraints; this poses a huge problem, particularly in underfunded schools, where in many cases the lack of funding for resources results in the dissection being omitted from the curriculum entirely (Zemanova, 2022). In some cases, schools may not have access to dedicated laboratory spaces, forcing dissections to take place in general classrooms, where hygiene and waste disposal have become major concerns (Jorquera and Vogel, 2021).

The quality of specimens also varies from school to school and specimen to specimen. In schools that are well-funded, the budget allows for the procurement of high-quality specimens that are well-preserved, but on the other hand, underfunded schools may not have the budget to do this and may only be able to do dissections on rare occasions when they receive donations from local abattoirs or butcheries. This means that the quality of the specimen may be compromised, which results in inconsistencies in the anatomical structure and integrity of the specimen. This in turn means that learners may not be able to conduct the dissection themselves if they may not be able to observe the structures that we are trying to identify (Kaiser et al., 2023).

2.3.7 Quality of the Specimens Used in Hands-on Dissections

If the quality of specimens used in hands-on dissections is of a high quality, it can improve the learning outcome, or if it is of a low quality, it can greatly hinder the learning outcome. When the specimen is of high quality, the learners are able to see the structures, and in turn, they are able to see how the structure is related to the function that it performs. There are many factors that affect a specimen's quality, including how and where it was obtained, how it was preserved, the health of the animal it came from, etc. These factors are made worse in South Africa because schools don't have enough resources, which leads to inconsistent specimen quality and, in the end, affects the learning experience (Bottia et al., 2022). This chapter also discusses the lack of resources in schools.

With regards to the sources from which specimens have been taken, specimens could be sourced from one of the following places: scientific suppliers, butcheries and abattoirs, or self-preserved specimens. If the specimens are sourced from scientific suppliers, the quality of the specimen is very high, as it has been pre-preserved and specifically prepared to be used for educational purposes; in this case, the specimen has not been cut open and therefore maintains anatomical integrity (Kaiser et al., 2023). Many South African schools source their specimens from abattoirs and butcheries, especially with regards to mammalian hearts, lungs, and kidneys. This is a more cost-effective solution; however, these specimens may vary in quality (Kavai et al., 2017). Furthermore, butcheries and abattoirs are often required to cut open the organ so that it is not sold on the black market, therefore making it difficult for learners to conduct the dissection and to identify structures. Another source is that of natural or self-preserved specimens; this is where some schools collect specimens from local farms or from the natural environments. This method allows for easy access to organic, fresh specimens, but it brings up ethical and logistical challenges related to handling, preservation, and disposal of the specimens (Zemanova, 2022).

Using poor-quality specimens during dissections can have a negative effect on learner participation, learning outcomes, and the development of practical skills. In such cases, valuable biological structures may become difficult to see and identify in specimens that have been damaged or poorly preserved; this decreases the effectiveness of the learning outcomes (Bogomolova et al., 2019). It may also bring about misconceptions regarding the organ's structure and function, as learners may not be able to see or differentiate between structures (Kurt et al., 2020).

Bad handling of specimens can also result in foul smells, which may cause discomfort, resulting in learners disengaging in dissections because of the unpleasant odours (Kaiser et al., 2023). This is especially troubling because the goal of practical dissections is to boost learners' interest and involvement in the Life Sciences classroom.

2.3.8 Teacher's pedagogical approach for hands-on dissections

In the classroom, the approaches that teachers employ are of utmost importance; it is therefore imperative for teachers to have adequate skills and techniques in order to carry out hands-on dissections. Life Sciences education is heavily reliant on the competence and confidence of the teacher conducting the dissection. It is not merely about creating a clear understanding of biological structures and the associated functions but also about reinforcing this knowledge and teaching the necessary technical skills. However, research suggests that many teachers that were trained in earlier educational systems may lack the necessary practical experience with dissections (Koehler et al., 2013). This results in the need for training programs that ensure that teachers are well-equipped to facilitate meaningful and engaging dissection experiences for learners.

The prior experience of teachers as well as their individual perspectives influence the manner in which they approach laboratory work. Some teachers may have a great deal of experience with laboratory-based teaching, while others may not feel comfortable conducting dissections due to ethical or religious reasons, personal discomfort, or a lack of technical proficiency (Teo et al., 2007).

According to Abel et al. (2022), the success of hands-on dissection is directly related to the teachers' pedagogical confidence and attitudes toward using dissection techniques. An adverse perception of dissections or a lack of confidence when performing them will in turn adversely impact learner engagement and learning outcomes.

When conducting teacher training programs, there should be ones that address the theoretical components of Life Sciences. In addition, it is necessary to have sessions that cover the practical and applicational components of dissections as well. This can be done by including structured training on specimen handling, safety procedures, and strategies to accommodate diverse learner needs (Jeyakumar et al., 2020). In order to build the confidence of teachers with regards to dissections, other sessions could include supervised and guided practicals so as to ensure that the teachers are comfortable with conducting dissections and that they have practical experience with them so that they are able to address concerns and questions from learners when using the approach in their classes. In addition to this, the use of mentorship programs can also be employed by pairing up more experienced teachers with less experienced teachers in order to foster support and assistance. Such mentorship programs have been found to improve instructional quality in practical science education (MacPherson and Lisk, 2022).

In order to maximize the educational value of dissection, teachers must also be skilled in promoting inquiry-based learning in their lessons. This requires teachers to firstly facilitate active participation in exploration of structures in order to improve comprehension and retention (DeFeo et al., 2020). Additionally, teachers must be able to guide discussions that direct learners to make observations, form hypotheses, and analyse their findings in doing so teachers are able to promote the development of scientific inquiry and problem-solving skills in learners (Zumwalt et al., 2022).

2.4 Attitudes and psychosocial impacts of hands-on dissections

2.4.1 Cognitive and psychological impacts of dissections on learners

The cognitive development and psychological engagement of a dissection, whether simulated or hands-on, are undeniable. Hands-on dissections bring sensory-motor learning into play, which enhances memory retention and understanding of the concept being taught (Reedy, 2015). The physical actions taken when dissecting allow for multisensory feedback that strengthens cognitive processing, which in turn helps learners create mental representations of (Meijer et al., 2019).

In cases where learners are squeamish of blood, hands-on dissections can cause some learners to feel uneasy, anxious (Lai et al., 2023b) when required to dissect an animal; this negatively impacts their participation, as many learners avoid the interaction, and in turn, has a negative impacts their learning experience and outcomes (Thisgaard and Makransky, 2017). However, this could be overcome by using artificial specimens (Kavai et al., 2017). The teacher could also employ ICT-simulated dissections, as they would minimize psychological distress while still allowing learners to engage with the subject matter (Zhang et al., 2022). This in turn also raises ethical concerns or religious concerns about the use of animal organs, which I will discuss later in this chapter.

2.4.2 The influence of cultural and religious beliefs on dissection practices

Cultural and religious beliefs significantly influence learners' willingness to participate in dissections. Some cultures prohibit the handling animal remains as it is deemed inappropriate (Meyer and Sherrill, 2020). Religions such as Hinduism and Islam stipulate dietary laws may prohibit the use of certain animal specimens. In such cases teachers must provide alternative learning tools such as simulated dissections. It is for this reason that many educational institutions have implemented policies allowing learners to choose not to conduct a hands-on dissection and therefore favour educational alternatives (Kline, 1995). In doing this, teachers are able to create an inclusive learning environment that respects diverse perspectives, which is crucial for maintaining learner engagement in Life Sciences education (Miller and Fraser, 2023).

2.4.3 The psychological effects of dissections on learners

The psychological impact of dissections varies among learners, with some experiencing fascination and others discomfort or distress (Lai et al., 2023b). Research suggests that exposure to dissections can provoke anxiety, particularly among learners who are sensitive to blood or animal remains (Weil et al., 2019). But studies also show that exposing learners to simulated dissections before they actually do one can lessen the negative psychological effects by getting them used to the process. Teachers play a critical role in ensuring that learners are emotionally prepared for dissections by offering guidance, ethical discussions, and alternative yet inclusive learning methods (Arun, 2017).2.4.4 Ethical considerations in dissections

The ethical implications of using animal specimens in education have been a topic of ongoing debate. Animal rights organizations argue that the procurement of specimens raises moral concerns about the treatment of animals before their use in dissections (Balcombe, 2019). Some studies indicate that learners who engage in dissections may become desensitized to animal suffering, potentially diminishing their empathy toward living creatures (Zemanova, 2022). However, others contend that dissections provide an invaluable educational experience that cannot be fully replicated through virtual simulations. Ethical guidelines in science education now encourage the use of alternative methods whenever possible to reduce harm to animals while still maintaining educational effectiveness (Zemanova, 2022).

2.5 ICT-Simulated dissections

2.5.1 The importance of ICT-simulated dissections in Life Sciences education

As of late, ICT-simulated dissections have become a progressively significant tool in terms of life science education; they offer a feasible alternative to hands-on dissections, or in other cases, they complement hands-on dissections to improve the understanding of complex biological processes without crossing ethical boundaries while concurrently reducing costs (Zubek et al., 2024).

One important thing about ICT-simulated dissections is that the virtual world can make an environment that can be controlled and repeated, which helps people remember the idea (Kurt et al., 2020). Another benefit is that it is easier for people to access; this means that ICT-simulated dissections are more open to people who don't have access to the real specimens (Hu et al., 2021). In addition, ICT-simulated dissections minimize health and safety concerns (George et al., 2022).

According to Lazarinis et al. (2020), research has demonstrated that ICT-simulated dissections are equally as effective when it involves developing critical and problem-solving skills (Lazarinis et al., 2020). Furthermore, for learners that are squeamish or have blood phobias, a possible trade-off alternative could be to have artificial hearts (Kavai et al., 2017). Despite ICT-simulated dissections lacking the tactile component that advantages hands-on dissections, they offer enhanced interactivity through simulations such as 3D models, animations, etc., often leading to a higher level of learner satisfaction compared to traditional methods (Zubek et al., 2024).

According to Zubek et al. (2024), ICT-simulated dissections are a safer and more moral way for learners to learn about different organs over and over again without having to worry about physical resources. It also allows the use of interactive tools like 3D models and quizzes that can reinforce learning and offer immediate feedback, ensuring that learners grasp difficult concepts (George et al., 2022).

2.5.2 The Use of Gamification and Virtual Reality in Dissections

The era that we are living in is one of technological advancements, when looking at dissections done through simulations, we see that they have a gamification and virtual reality (VR) aspect, making them increasingly popular as they offer interactive and immersive experiences. This boosts learner engagement significantly (Erolin et al., 2019). The interactive nature and popularity of using technological advancements can be seen in quizzes and achievements, and real-time feedback can improve motivation and knowledge retention (Bouchrika et al., 2019). As learners in this era are greatly influenced by technology, simulated dissections increase their interactivity and engagement compared to hands-on dissections without ethical concerns (Zemanova, 2022). This may also become an integral component of future anatomy education, or it may further complement traditional hands-on methods (Islam et al., 2024).

2.5.3 Challenges and limitations of ICT simulated dissections

Zhang et al. (2020) is of the opinion that ICT simulations may not provide the tactile element of learning, resulting in the loss of fine motor skills and physical manipulation techniques.

For ICT simulations to run smoothly, there needs to be access to adequate technological infrastructure; this includes computers, tablets, or virtual reality-sustaining equipment. Without technological support and connectivity, conducting the dissection correctly may not be possible (Zhang et al., 2020). ICT-simulated dissections further require a certain level of competence with the software as well as the educational purpose of the simulation. A minor inaccuracy or an oversimplification within a system simulation can easily lead to a misunderstanding, resulting in partial understanding by learners (Zhang et al., 2020; Palloff and Pratt, 2019).

In the viewpoint of Hou and Ouyang (2024), it is vital that simulations should not replace the provision of traditionally oriented teaching methods. There arises a need to balance virtual and physical real-life experiences when dealing with simulations (Hou and Ouyang, 2024).

However, experts say that ICT-simulated environments aren't perfect because they don't offer tactile feedback (Islam et al. 2024). ICT-simulated dissections don't help people learn how to solve problems like hands-on dissections do. This is because ICT simulations use standard, predictable models (Lazarinis et al., 2020).

Simulated dissections have a reliance on infrastructure, software, hardware, and, in many cases, internet connectivity and electricity; if any of these are inaccessible or not working correctly, the simulation may not work as required or at all (Shilongo, 2023).

2.5.4 The Impact of School Resources on ICT Simulated Dissection Quality

With regards to simulated dissections, there is a great need for technological infrastructure. The ICT simulated dissection requires a specific type of infrastructure, which includes software and hardware components like computers, stable internet connections, and specialized apps, among others. Each school will have access to different resources, therefore creating significant variations in the quality and effectiveness of the learning experiences. The different levels of resources, or lack thereof, that are available at different schools often reinforce socio-economic inequalities in science education (Bottia et al., 2022).

Simulated dissections depend on having the right technology in order to work (Hu et al., 2021). This is because they are seen as an ethical and cost-effective alternative to real dissections. Schools without computers, tablets, or internet access cannot implement simulated dissections because they lack the necessary tools. In other cases, outdated or insufficient resources or connectivity can result in low-quality graphics, lagging, or system crashes; this, in turn, will negatively impact the effectiveness of the learning that takes place (Shilongo, 2023).

Underfunded schools may not be able to afford the initial setup costs of high-quality simulated dissection software or the hardware required for it; even in cases where there is free software, there are often features that can only be unlocked with a paid version (Lazarinis et al., 2020). Well-funded schools have the budget to cover the costs of these advanced tools, providing learners with a more immersive and engaging learning experience compared to learners in less privileged institutions.

Teacher competency and training also play an important role in the effectiveness of simulated dissections. Funds should also be allocated for training so that teachers are familiar with the functions that simulated dissections have to offer; it is also valuable to equip teachers with the skills to effectively implement the technology into their lesson plans (MacPherson and Lisk, 2022).

2.5.5 Teacher's pedagogical approach for ICT simulated dissections

Teachers must use these teaching methods when doing any kind of dissection, as we've already talked about in the sections on question-based learning and problem-solving skills in a broader sense.

Research suggests that when conducting ICT simulated dissection inquiry-based learning, it encourages learners to explore anatomical structures. This is particularly valuable as the ICT simulation when learners are directed through guided questioning and problem-solving (De Jong et al., 2021). The type of training programs offered to teachers should therefore include methods in which teachers can facilitate active learning and encourage learner exploration.

More specific to ICT simulations is the need to be competent in the utilization of digital tools that are becoming more and more integrated into life science education.

In order to effectively use a simulated dissection, the teacher needs to know how to effectively utilize these technologies in the classroom (Zubek et al., 2024). The effectiveness of ICT-simulated dissections is directly related to a teacher's competence in using them as instructional tools. Abel et al. (2022) suggest that many teachers struggle to use ICT-based simulations in their teaching because of a lack of formal training and confidence in using digital tools and platforms (Abel et al., 2022). Teachers should be given access to development programs that equip them with the necessary skills to implement simulated dissections effectively in their classrooms.

Digital literacy and technical proficiency are necessary for the execution of simulated dissections. There are numerous teachers, many of whom were trained before the increased commonality of the adoption of ICT in classrooms, who are often not familiar with the interactive features of simulated dissection tools (Koehler et al., 2013). It is therefore important for training programs to make practical use of simulations so as to ensure that the teacher is familiar with the simulation software and has experience using it so that they can navigate the interface, access relevant features, and troubleshoot common technical issues (Lazarinis et al., 2020). If teachers are not provided with adequate training, they may not use the full potential of the simulated dissection; this in turn will reduce the effectiveness of the lesson and the learning tools (Zhang et al., 2020).

These teacher training programs should be ongoing rather than one-off programs, as the software and hardware are ever-changing. Additionally, continuous professional development, peer collaboration, and access to resources can help teachers stay up to date (MacPherson and Lisk, 2022). It is also suggested by Bogomolova et al. (2019) that mentorship programs be implemented so that experienced teachers can give support and guidance to less-experienced teachers in the use of simulated dissections; this will also improve confidence and instructional quality in science education.

2.5.6 Uses and effectiveness of ICT simulations in Life Sciences

As stated by Xiao and Adnan (2022), ICT simulations make Life Sciences education more accessible to learners by allowing them to interact with the knowledge in a dynamic manner that stimulates learner augmentation and learning. Complicated processes such as cellular processes, genetics, ecology, and anatomy have been imparted in the classroom using ICT simulations. They use multimedia elements, interactive models, and virtual experiments to aid the learning process. In the case of Snir et al. (1993), they say that ICT simulations greatly improve learners' conceptual understanding and ability to remember scientific principles by putting abstract ideas into real-life situations. As you can see, problem-solving as part of the curriculum and incorporating ICT simulations as learning experiences help teachers bring together theoretical knowledge with real-world applications in the Life Sciences.

Erolin et al. (2019) found that methodologies that use the virtual models and animations to display anatomical structures and processes create a more interactive learning environment. In the same way, Owolabi and Bekele (2021) said that virtual dissection, which is used to study details of anatomical structures, lets users interact with virtual tools and see the structure more than once without being limited by physical resources. They are particularly useful in overcoming logistical issues related to traditional dissections, such as specialized laboratory facilities, ethical issues about animal utilization, and variations in specimen quality.

2.5.7 The impact of ICT-simulated dissections on learner engagement

ICT-simulated dissections provide an interactive learning platform that caters to different learning styles. The ICT simulation mitigates ethical concerns, providing a calm alternative that can increase learner participation (Thisgaard and Makransky, 2017). ICT-simulated dissections are great for visual learners because they include 3D models and animations, which make it easier for learners to identify body parts (Erolin et al., 2019). ICT simulations get learners involved, especially when they make the dissections more like games, which also helps them concentrate and remember what they've learned (Bouchrika et al., 2019). There is an added element of control in simulated dissections that increases curiosity and critical thinking (Mayer, 2020).

2.5.8 The role of ICT simulated dissections in developing practical ICT skills

ICT-simulated dissections are used to enhance biological understanding, but they also play an important role in skills development, specifically digital literacies as well as ICT skills and competencies. This is increasingly important as we are entering a more digital era, and such skills are essential in the professional and academic world (Thisgaard and Makransky, 2017). The use of ICT simulations also promotes computer proficiency and problem-solving skills (Lazarinis et al., 2020). This may also be beneficial in future careers, particularly in STEM careers, healthcare, and research-based professions, where there is a large amount of new technologies that include the use of augmented reality (AR) and virtual reality (VR) (Islam et al., 2024).

2.5.9 Technological advancements in ICT simulated dissections

Advanced educational technologies have revolutionized the dissection process in Life Sciences education. Innovations such as high-resolution 3D imaging, augmented reality (AR), and artificial intelligence-driven simulations provide interactive and immersive learning experiences (Mese, 2023). These advancements allow learners to manipulate anatomical structures in real time, providing a level of interactivity that enhances learning outcomes. Additionally, AI-powered learning systems can tailor dissection exercises to individual learner needs, offering personalized feedback and adaptive challenges (Zemanova, 2022).

2.5.10 Stigmas surrounding the use of ICT

Online learning has often been perceived as having a lower quality of learning and meaning making in comparison to face-to-face learning. This is largely due to the fact that online learning is often confused with the emergency response to a disaster such as COVID-19 (Hodges et al., 2020). In reality, the kind of learning that took place during the pandemic was not able to take full advantage of online learning as it was not planned and implemented in the manner in which it is optimal (Hodges et al., 2020). I will further explain the differences that are to be made note of and my choices during the study in the next subheading.

First and foremost, it is of great importance to differentiate between emergency remote learning and other systematic online learning. Researchers in the field of educational technology have clearly shown that well-planned online teaching and learning is significantly different from cancelling face-to-face teaching and learning because of an emergency or crisis (Hodges et al., 2020).

For the purpose of my study, I will be focusing on simulations done in a systematically planned manner, and more specifically, on experiments conducted in a face-to-face setting using a simulator or smartboard. This is increasingly difficult as the literature and experiences that are available are based largely on how the education system functioned during the Covid-19 pandemic.

2.5.11 Learner attitudes toward ICT simulated dissections

As simulated dissections gain popularity, research has examined learners' attitudes toward this mode of learning. Some learners appreciate the accessibility and ethical advantages of simulated dissections, particularly those who are uncomfortable working with real specimens (Lazarinis et al., 2020). However, others argue that simulated dissections lack the realism and depth of experience offered by hands-on methods (Kavai et al., 2017). Studies have shown that when learners have access to both virtual and physical dissections, their overall comprehension and satisfaction improve significantly (Zubek et al., 2024). Thus, integrating simulated dissections as a complementary tool rather than a replacement may be the most effective approach (Hu et al., 2021).

2.5.12 Pedagogical and instructional design opportunities

According to Alharbi et al. (2020), these ICT simulations show many ways that instructional design can be changed to make learning better by accommodating different pedagogical needs. Further, ICT simulations empower teachers in their preparation and modification for learning environments, individual access to given types of content, and testing collaborative learning via virtual environments. Interactive features, like real-time feedback with data visualization tools, are designed to encourage active learning by making the user want to work on a certain task. This makes learning more effective. Besides, Zhang et al. (2020) state that ICT simulations support differentiated instruction to cater to diverse learning styles and foster self-directed learning. Simulation-based scenarios can be used in education to mimic real-life problems and, hence, set a ground for younger learners to practice with challenges that may be their future scientific, technical, or engineering professional lives. Therefore, simulation further extends interest in learning, explores the complexity of conceptual content, and, more significantly, fosters digital literacy, which is highly needed in 21st-century education.

Koehler et al. (2013) argue that society and institutions are often unsupportive of teachers' attempts in brining technology in their classrooms, however the reality of it is that in many cases, teachers do not have the adequate experience with using technology for teaching and learning to do so. Some teachers obtained their qualifications at a time when educational technology was not as advanced as in the present day; hence, they do not consider themselves as adequately prepared to use technology in their teaching and learning (Koehler et al., 2013). According to Abel et al. (2022), the evidence on how ICT has been successful in schools is minimal; this is partially due to the fact that there are no clear ICT educational strategies in place to improve the pedagogical skills for teachers, which include practicals" (Abel et al., 2022). However, it's crucial to acknowledge that teachers must demonstrate competence in conducting hands-on experiments.

The teacher's attitude towards ICT also needs to be looked into, as it influences the success of ICT integrations in classrooms (Abel et al., 2022). It is often found that a negative attitude toward ICT results in teachers resisting attempts to integrate it in their classrooms (Teo et al., 2007), even more so in practicals. This negative attitude may often stem from a lack of competence in ICT or in ICT simulations (Palloff and Pratt, 2019).

2.6 Comparing ICT simulations and hands-on dissections and a hybrid approach

2.6.1Comparing ICT simulations and hands-on dissections

According to Cavicchi (2008), when learners move on to a simulated mode of experimentation, they don't get to use the real equipment. As a result, they can't learn the skills and muscle memory they need to do the experiment themselves (Cavicchi, 2008).

On the other hand, we find ourselves on the brink of the fourth industrial revolution; this revolution is a step into the digital world. It can be argued that by doing simulations of dissections we are allowing learners to hone a different type of skill that will be expected of them in the very near future (Cavicchi, 2008).

Two different ways to teach life science are through ICT-simulated dissections and hands-on dissections. Each has its own pros and cons (Kline, 1995; Zemanova, 2022). Hands-on dissections grant real learning experiences that lead to the development of efficient skills for learners in using their hands, as well as gaining a spatial understanding of the anatomy. They create close contact with biological specimens, consequently developing a practical approach to learning that is hard to simulate in a virtual environment. On the other hand, the benefits of using ICT simulations lie with accessibility, scalability, and cost-effectiveness. They eliminate all ethical considerations associated with animal use and learning. In a similar context, Zhang et al. (2020) stated that this approach also supports simulated repeated experimentation and investigations within a fully controlled digital environment. However, because some physical sensation and sensory immersion seem to be taken away from the actual experience of dissecting, the tactile sensation aspect that might make it harder for learners to practice their skills and understand their surroundings is not felt. What kind of balance should there be between the teacher's goals for the learners' learning, the resources that are available, and the learning outcomes that can be achieved through ICT simulations or the old-fashioned dissection method? This integrated approach would balance learning more toward the strengths of the two approaches or methods, engaging the learner comprehensively in general life science education.

In the opinion of Dauer and Dauer (2016), the use of ICT simulations as a medium for teaching potential mammalian hearts to the learners is excellent due to its interactivity and visual appeal. Through the application of 3D models, animations, and virtual experiments, learners can interact with models and visualize the structure-function correlation of the heart. They can manipulate variables and see designed real-time responses to develop a profound understanding of both the anatomy and physiology of the heart. However, Xiao and Adnan (2022) say that using simulations in ICT helps learners learn because, after enough practice and self-exploration, they can use what they've learned in the classroom in real life. So, the learning outcomes would be better fact memorization, better critical thinking, and the ability to break down complicated biological processes in a controlled setting.

Conventional hands-on dissections lend a memorable, unique learning experience in understanding the mammalian heart. By simply observing and manipulating organ samples of honest hearts, learners are provided sensory experiences and, perhaps more importantly, a feel for the scale on which more detail in anatomy and function is developed. Because learners work directly with tissues and organs, Picatoste et al. (2017) say that hands-on dissections improve manipulative skills and help learners understand biological ideas better. Thus, learners can visualize morphological differences in the heart and the complexities of its anatomy. The sensory perception made practical by physical involvement in traditional dissections helps drive theoretical knowledge.

2.6.2 The importance of hybrid dissections in Life Sciences education

As we already said, ICT-simulated dissections and hands-on dissections often work well together. For example, Darras et al. (2019) found that the best and most complete learning happens when ICT-simulated dissections are combined with hands-on dissections. The study also says that learners who do both types of dissection tend to understand anatomy better and do better on tests than learners who only do one type of dissection (Kurt et al., 2020).

A mixed method uses the best parts of both hands-on and ICT-simulated dissections. It gives learners the real-life, tactile experience of hands-on dissections and the adaptability and ease of access of virtual environments (Hu et al., 2021).

In many instances it has been found that when both methods are used together, this combination caters to different learning styles and as a result will spark learner engagement (Kurt et al., 2020). As a result, learners exposed to both modes of dissection perform better on assessments (Bogomolova et al., 2019). Furthermore, combining the approaches addresses ethical concerns and logistical challenges, ensuring that all learners have equal access to high-quality anatomy education (Hu et al., 2021). Using both real-life dissections and computer-simulated ones in life science classes helps learners understand anatomy better, encourages them to think critically, and makes the learning experience more fun and open to everyone.

2.6.3 The role of hybrid learning in anatomy education

Hybrid learning, which integrates both virtual and hands-on dissections, has been shown to be the most effective method for teaching anatomy (Kurt et al., 2020). When traditional dissections are mixed with digital simulations, learners get the best of both worlds: the tactile experience of dissection and the interactive features of technology-enhanced learning (Hu et al., 2021). The study by Bogomolova et al. (2019) shows that learners who use hybrid learning are better at remembering anatomy facts and are more confident when using them in real life. Hybrid learning approaches address accessibility issues while maintaining the hands-on experience crucial for developing laboratory skills (Zhang et al., 2020).

2.6.4 The Role of Dissections in Preparing Learners for Future Medical Studies

When learners conduct dissections, regardless of whether it is hands-on or simulated, it prepares leaners for future medical studies, this is because dissections provide foundational knowledge of biological components, particularly in anatomy. Dissections also promote skills development, and in turn spark interest in learner for careers health sciences. It offers a realistic and immersive experience this develops skills that are required in medical and health science fields (Kaiser et al., 2023). It also teaches learners how to properly handle specimens, which hones fine motor skills, hand-eye co-ordination, and precision (De Villiers and Monk, 2005). Hands-on dissections introduce learners to ethical issues and the emotional challenges this makes them more emotionally aware which is an important aspect when considering a medical or health sciences career (De Villiers and Monk, 2005).

On the other hand, simulated dissections offer another feasible option which integrates technology into health care and considering that this is the direction in which modern medicine is going in, confidence and comfort in using them is valuable for careers in the field (De Villiers and Monk, 2005; Zemanova, 2022). In cases where learners are exposed to a hybrid model of learning they are provided with a well-rounded foundation that prepares them for professional careers (Hu et al., 2021).

2.6.5 The Impact of Dissections on Learner Motivation and Interest in Science

Dissections provide a different approach to daily teaching practices and have the ability to spark learners' interest in Life Sciences, which will influence their attention to the subject and later their career choices (Jeyakumar et al., 2019). Bogomolova et al. (2019) suggests that dissections help spark interest and motivation in learners, this is because dissections provide them a hands-on and/or immersive learning experience. Hands-on dissections create this interest through physical exploration and tactile elements, while simulated dissections provide a technologically inclined interactive platform (Kurt et al., 2020). This once again links to the ability of dissections to spark learners' interest in STEM-related and health care careers education (MacPherson and Lisk, 2022).

2.6.6 Role of Hands-on and ICT-simulated dissections in Cognitive Load and Information Processing

The Cognitive load theory as proposed by Sweller (2011) suggests that the presentation of information has a direct influence on the learner's ability to process and retain it (Sweller, 2011). Hands-on dissections are a multisensory activity stimulating visual, tactile, and olfactory sense simultaneously, this can be useful, or it can be a hinderance based on the individual learner's cognitive capacity (Duran et al., 2022). On the other hand, ICT-simulated dissections reduce the cognitive load as they provide a more coherent sequence with step-by-step prompts thus facilitating comprehension (Lazarinis et al., 2020). If teachers are familiar and comfortable with the cognitive demands of each method of dissection, they are then able to an optimize lesson in order to enhance learner learning and retention (Zemanova, 2022).

2.6.7 The influence of learning styles on dissection outcomes

Each individual learner has a unique learning style and based on the way in which they process information, the effectiveness of dissection as a teaching tool can vary. In the case of visual learners, they often benefit from simulated dissections because this mode of dissection provides clear, high-resolution images of biological structures, with interactive labelling (Lazarinis et al., 2020). On the other hand, kinaesthetic learners, often learn best through sensory experiences, therefore find hands-on dissections more engaging and beneficial for their understanding (Kaiser et al., 2023). According to Zubek et al. (2024), using a hybrid model or a multi-modal approach that brings in elements of both hands-on and simulated dissection is the optimal solution to meet the needs of all kinds of learners. When teachers who understand and accommodate different learning styles, they are more likely to improve the overall comprehension and engagement of learners (Bogomolova et al., 2019).

2.6.8 The importance of spatial awareness in anatomy education

Dissections allow learners to understand spatial awareness, this is because when learners are physically working the specimens, they are exposed to a three-dimensional perspective it (Dauer and Dauer, 2016). This is very beneficial in medical education (Bogomolova et al., 2019). In the case of simulated dissections, it can also enhance this understanding as the simulations allows learners to rotate, zoom, and manipulate the model, this provides learners with views of the organ that may not be able to be observed using hands-on dissections (Zemanova, 2022). Overall, it has been seen that learners who conduct hands-on dissections tend have a better perception of spatial reasoning in comparison to those who rely solely on digital methods (Hu et al., 2021). Once again this brings into the discussion the use of a hybrid model which incorporates both simulated and hands-on methods in order to improve spatial understanding.

2.6.9 Learner views and perceptions toward ICT simulations and hands-on dissections

Since we live in a very digital world now, learners often find that ICT simulations are interactive and have simple features that make it easy to create visual and manipulative learning scenarios on a platform they are already familiar with (Lee et al., 2006). Simulations provide learners the ability to manipulate the process of studying complex biological processes in a low-risk environment (Thisgaard and Makransky, 2017). It is helpful that they are able to go back to the exercises for repeated practice (Thisgaard and Makransky, 2017). Working with virtual specimens is often seen as a more ethical option than working with animal specimens for dissection (Arun, 2017). However, some learners express concerns about the loss of many details in physical feedback and the potential oversimplification of real-world complexities in simulations (Chernikova et al., 2020).

Comparatively, hands-on dissections, as stated by Hou and Ouyang (2024), are considered authentic and give a real feeling. Many learners associate accurate dissection with understanding anatomical structures and physiologies through the touch of specimens (Arun, 2017). They are considered to have made them appreciative of acquiring real experience and growing a more profound attachment to the subject matter (Arun, 2017). Cited challenges include ethical dilemmas of animal use, high-quality specimen acquisition, and other logistics (Thisgaard and Makransky, 2017; Jeyakumar et al., 2019b). The general approach to instruction regarding learner preferences depends on educational objectives, personal learning styles, and cultural orientation (Kulkarni et al., 2021). So, teachers need to know what learners think in order to choose the best way to teach that balances the pros and cons of traditional dissections and ICT simulations for creating well-rounded learning experiences in Life Sciences (Arun, 2017).

2.7 The future of dissections in Life Sciences education

As science education evolves, the future of dissections is likely to involve greater integration of digital technologies. Augmented reality (AR) and virtual reality (VR) are becoming more common, which means that traditional dissections may not be done as often as high-tech alternatives (Zhang et al., 2022). Also, 3D bioprinting and synthetic organ models are becoming useful for hands-on dissection without the ethical problems that come with using animal specimens. This will be especially helpful for learners who find it hard to work with animal tissue or blood (Kavai et al., 2017). While hands-on dissections will likely remain valuable, future education strategies may focus on balancing traditional and digital methodologies for a more inclusive and effective learning experience (Zemanova, 2022).

2.8 Addressing Resource Inequalities

Schools need to address multiple different issues in order to overcome the lack of resources for hands-on dissections and simulated dissections. There is a need for a budget for equipment procurement and resources as well as professional development programs in order to close the gap between under-resourced and well-resourced schools (Bottia et al., 2022). Another way to mitigate the problem would be to create partnerships with possible donors and institutions that may facilitate the provision of subsidized or donated materials; this will ensure that the learners are provided with access to high-quality life science education (Zhang et al., 2020).

A possible means of addressing this problem would be to employ hybrid approaches, where both methods of dissection complement each other, and therefore when one method lacks resources, the other may be able to mitigate resource limitations. For example, if a school has limited access to physical specimens, it can use simulated dissections as preparatory tools before engaging in hands-on activities (Kurt et al., 2020). Similarly, mobile-based simulation tools don't usually need a lot of technical setups. This means that learners in some low-resource settings can do simulated dissections more easily (Hu et al., 2021).

2.8.1 The influence of socio-economic factors on access to dissections

Socio-economic disparities in turn determine the availability of resources for dissection, this varies greatly from one educational institution to the next (Bottia et al., 2022). Low-income schools areas may not have the budget to afford resources such as biological specimens, dissection tools, and laboratory facilities, this in turn limits learners' opportunities to engage in hands-on learning. Simulated dissections have been found to potentially provide a cost-effective alternative that can be accessed with minimal infrastructure (Hu et al., 2021). However, digital inequality remains a challenge, as learners in underprivileged communities may lack reliable internet access or necessary technology to fully engage in simulated dissections (Liu and Rivera, 2020). Addressing these inequalities through funding initiatives and policy changes is essential to ensure that all learners have access to comprehensive anatomy education (Zhang et al., 2020).

2.9 Research gap

Even though there has been useful research on ICT-based simulations and information gathered in support of hands-on dissections to improve the learning experience in Life Sciences education, there is an enormous need for more research that compares how well different learning environments meet certain learning goals. For example, earlier studies used broad theoretical frameworks a lot more than they looked closely at how learners learned and how well they did in school by analysing their actual learning experiences. Further, few studies have systematically examined learner preferences and perceptions of these ICT simulations about traditional dissection settings, thereby limiting an understanding of effective instructional strategies and pedagogical practices. To put it another way, these are gaps that need to be filled with evidence-based approaches to curriculum development and educational policy that aim to give all learners equal access to high-quality science education.

2.10 Theoretical framework

There are many theoretical frameworks related to my study; My study draws upon several well-established educational theories listed below:

2.10.1 Constructivist Learning Theory

2.10.2 Experiential Learning Theory

2.10.3 Cognitive Load and Multimedia Learning

2.10.4 Technology Integration and the TPACK Framework

2.10.5 Hybrid Learning and Blended Approaches

Thereafter I will explain the most relevant education theories from the above-mentioned ones.

2.10.1 Constructivist Learning Theory

The constructivist learning theory, stems from the work of Vygotsky (1978), the story speculates the need of direct interactions with the environment in order for learners to actively construct knowledge rather than passively absorbing information.

In the context of my study this stance is particularly applicable as we compare hands-on dissections where the learner is able to directly manipulate the specimen, thus providing tangible experiences that allow learners to formulate their own understanding of anatomical structures (Vygotsky, 1978). The experience is multisensory and assists in developing a better understanding of the relationships between structures and functions of the organ, in turn creating a mental model that represents their understanding. For example, the process of identifying the septum or valves is greatly enhanced when learners can see and feel the specimen (Vygotsky, 1978).

With regards to ICT simulated dissections although they lack the tactile element of hands-on dissection, the learners are able to explore the organ though 3D models and animations of the heart using visual and interactive engagement which supports cognitive knowledge construction. ICT simulations also offer repeatability where learners are able to reset and start the complex process again, enabling them to reconstruct their understanding of the concept in a step - by - step manner at their own pace.

The constructivists' view supports both methods as it is a learner - centred and active experiences regardless of whether it is hands-on or virtual.

2.10.2 Experiential Learning Theory

The Experiential learning theory as stated by Kolb (1984) highlights the cyclical processes through which learning occurs, it involves multiple aspects such as concrete experiences, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984).

Taking this into consideration for my study, hands on dissections are a textbook instance of concrete experiences, where learners engage directly with a specimen which is a sensory and active experience, after they have experienced this they are able to reflect on what they have observed and integrate it their theoretical knowledge of the concept, this results in abstract conceptualization of the mammalian heart. In the same breath ICT simulations also support this cyclic manner of learning but allowing repeated experimentation, where learners are able to virtually dissect the heart multiple times, the animations further allow the learners to observe complex process such as blood flow and the cardiac cycle. Both dissection modes offer unique but complementary experiences that promote learning as outlined by Kolb (1984).

2.10.3 Cognitive Load and Multimedia Learning

Sweller (1988) proposed the Cognitive Load Theory which stipulates how working memory can be overwhelmed by complex tasks, in 2009 Mayer's Multimedia Learning Theory (Mayer, 2009) was subsequently proposed, which provided guidelines for designing effective educational materials to promote cognitive processing.

In the case of hands-on dissection, the complexity of the dissection and specimen coupled with the sensory inputs may result in high cognitive load due. For example, this mode of dissection required learners to observe the three - dimensional structure of the heart, recognize different tissues, and draw conclusions on the function of each structure of the heart while simultaneously handling a real specimen. This high cognitive load could possibly decrease the effectiveness of the learning experience if not done in a proper manner.

With the case of the ICT simulation, the dissection can be designed and manipulated to limit the chances of cognitive overload taking place. This can be achieved by breaking up the information into smaller parts that are easier to understand, providing clear annotations, and using animations for specific processes such as the flow of blood through the heart. Further the simulations can be manipulated to display isolated structures or to show them in a different colour in order for learners to label it therefore reducing the cognitive burden and in turn helping learners understand the concept more easily. Therefore, if used correctly multimedia learning theory can be an effective educational tool when it is used to complement hands-on experiences.

2.10.4 Technology Integration and the TPACK Framework

The Technological Pedagogical Content Knowledge (TPACK) framework (Mishra and Koehler, 2006) allows us to view the integration of ICT simulations into the classroom. According to TPACK framework in order for technology to be well integrated, it requires teachers to blend subject knowledge, effective pedagogical strategies, and appropriate technological tools.

Integrating technology into educational practices requires more than just access to digital tools; it demands a thoughtful combination of content, pedagogy, and technological proficiency.

For my study the effectiveness of ICT simulated dissections cannot be only based on the quality of the simulation software but also on how well it is incorporated into the classroom. Teacher competence with regards to these digital tools is important. By framing technology integration within the TPACK model, this study highlights the importance of teacher preparation and the need for professional development in digital literacy as essential components of modern science education.

2.10.5 Hybrid Learning and Blended Approach

Recent research in educational practices suggests that a hybrid or blended learning approach that combines different learning approaches may result in superior learning outcomes (Garrison and Kanuka, 2004). In the context of dissection in Life Sciences, and specifically in my study this model would bring together the tactile, experiential benefits of hands-on dissections with the flexibility, repeatability and clarity of ICT simulations.

This approach promotes learning as it accommodates different learning styles by creating multimodal lesson that benefits learners that are visual, auditory or kinaesthetic etc. The learners are able to gain from tactile and spatial experiences, hands-on dissections offer direct interaction with physical specimens, as well as the opportunity to revisit challenging concepts provided by ICT simulations. Moreover, a hybrid approach can address practical limitations such as ethical concerns, cost constraints, and logistical challenges associated with using animal specimens. This model promotes inclusivity and ensures that all learners have access to high - quality educational experiences regardless of the limitations of physical resources.

2.11 The most relevant educational theories for this study

Although this study draws on all of the above education theories, the most prominent theories are the following:

2.11.1 Constructivist Learning Theory

2.11.2 Experiential Learning Theory

2.11.1 Constructivist Learning Theory

As Vygotsky (1978) has argued, learners construct knowledge actively through direct engagement rather than passively absorbing information. With regards to hands-on dissections learners are able to physically manipulate specimens and with regards to simulated dissections they are able to use the digital platform to explore the simulated specimen, as such both methods support active, learner- centred engagement even though they both utilize different modalities.

This theory was appropriate for this study as it explains how both tactile experiences and interactive digital environments allow learners to create their own understanding of the anatomical structures being taught (Vygotsky, 1978).

2.11.2 Experiential Learning Theory

Kolb's (1984) theory emphasizes that learning is a cyclical process, this involves concrete experience followed by observation, abstract conceptualisation and then active experimentation. Hands-on dissections allow for concrete sensory experiences through which learners are able to make connections to the abstract concept, while ICT simulated dissections offer repeated experimentation and the visualization of complex processes such as blood flow which learners are then able to link to the abstract content that was taught (Kolb, 1984).

Both these theories provided a strong framework which was able to examine the effectiveness of hands-on, and ICT simulated dissections. The constructivists theory addresses how learners actively build knowledge through engagement, while the experiential learning theory explains the cyclical process through which knowledge is deepened and applied.

2.12 Chapter summary

This literature review addresses the evolving education system and highlights the urgent need for innovative approaches particularly by possibly using the hybrid approach to conduct dissections thus balancing the traditional hands-on dissection with the newer ICT simulated dissection. The chapter focuses on the limitations and affordances of hands-on dissections and simulated dissections.

Hands-on dissection allows for a tactile experience where learners can observe and manipulate the actual anatomical structure and as a result foster critical thinking, fine motor and other relevant skills. However, with hands-on dissections we face ethical, cultural or religious concerns as well as the cost and difficulty of specimen procurement.

With regards to virtual dissections, we are able to eliminate the ethical concerns and logistical challenges additionally in the long run it is more cost - efficient to conduct simulated dissections but this is only possible if the technological infrastructure, software are available. Another concern with regards to simulated dissections is teacher competency when using the software.

Chapter 3: Research Methodology

3.0 Introduction

This chapter covers the research methodology that was employed in this study; it includes the ontological and epistemological concepts that are transformed into standards, norms, and rules that form the basis of the direction my research takes, as well as recommendations that specify how my research was conducted. There are many different research procedures; therefore, a single approach cannot be suitable for every research situation, each with its own advantages and disadvantages (Nayak and Singh, 2021). Research methodology is used to investigate social processes, the natural world, and a wide range of subject matter. The methodologies and approaches that I have employed are both qualitative and quantitative, making it a mixed-method approach. These approaches are summarized below and will be expanded on later in this chapter.

One of the approaches I have discussed is quantitative research; this approach is primarily concerned with numerical data, statistical analysis, and objective measurement. It often identifies patterns and establishes relationships between variables (Creswell and Creswell, 2018). This approach often employs methods such as questionnaires, surveys, experiments, and standardized tests, ensuring the replicability and generalizability of findings (Muijs, 2020).

In terms of qualitative data, it is helpful for examining human perceptions and experiences without using numerical data; instead, it places an emphasis on subjective meaning, context, and depth of understanding (Denzin and Lincoln, 2018).

As my study uses both qualitative and quantitative approaches, it is categorized as a mixed-methods study. It uses both approaches to create a more comprehensive understanding of a research problem. This approach combined numerical analysis with subjective data, allowed me to explore not only what happens (quantitative) but also why and how it happens (qualitative) (Creswell and Plano Clark, 2021).

I will further explain these choices in this chapter. It is primarily focused on the specific details of how this study was carried out, addressing aspects surrounding the research approach and design, the sample and sampling procedure, and how the data is gathered, analysed, and evaluated for a scientific study (Balwan et al., 2022).

3.1.1 Research Paradigm

When comprehending and studying a phenomenon, the research paradigm is emphasized as it is defined by the conceptual strategy. The concept strategy, in turn, creates a research strategy by acting as the structure where the ideas and the procedures of the study can be incorporated based on the field of research (Kivunja and Kuyini, 2017). My study is centred around the pragmatic research paradigm; it emphasizes the use of approaches that best address the research questions and objectives. It uses aspects of positivism and interpretivism without rigidly aligning with either paradigm.

Positivist Paradigm

This paradigm is defined as the epistemological concept or the doctrine that is utilized to comprehend social and physical reality. Moreover, the distinct realities must be independent and completely unbiased of any external influences. The observation should also be done in an unbiased manner without causing any influence (Shaw, 2022). Due to the fact that parts of my study focuses on measuring learning outcomes objectively by assessing learners' understanding of the content, which can be measured and quantified through systematic investigation it partly aligns with the positivist's paradigm.

Interpretivist Paradigm

When it comes to gathering information regarding occurrences, the Interpretivist school of research encourages the comprehension of an individual's beliefs, ideas, motives, and thoughts. It is the concentration of the data and the gathered information and the attention to the context that distinctively sets the Interpretivist paradigm apart from the positivist ones (Lin, 1998). At the same time my study also explores learners' perspectives, challenges and experiences, this aligns with the interpretivist's paradigm.

Pragmatic Paradigm

Neither the positivists paradigm nor the interpretivists paradigm can completely address all the aspects of my study, as such the pragmatic paradigm was best suited. The Pragmatic Paradigm is a research approach that focuses on practical problem-solving by addressing both quantitative and qualitative approaches in order to create a complete and comprehensive view of the research problem. It is not as stringent as the purely positivist (quantitative) or interpretivist (qualitative) paradigms and highlights the importance of flexibility and feasibility to use the most effective methods to address the research question (Creswell and Plano Clark, 2018).

The pragmatic paradigm is also the paradigm that supports the use of mixed-method research. This is because, in mixed-method research, numerical data as well as unique and personal insights from the participants are used to form complete, well-rounded results and conclusions, as explained previously, which aligns well with the pragmatic paradigm (Creswell and Plano Clark, 2018).

When using the pragmatic paradigm, researchers are primarily concerned with the practical application of research methods. It is a highly practical approach as it appreciates the different contributions that different types of data bring in order to answer the research question holistically (Morgan, 2014). This, in turn, suggests that by using the pragmatic paradigm, we are able to blend both objective numerical data and subjective experience-based information in order to create a complete picture of the data collected (Tashakkori and Teddlie, 2010).

The Pragmatic Paradigm is best suited for my study as it is a comparative study that addresses hands-on and ICT dissections in Grade 10 Life Sciences. The research aims to address a practical problem faced by teachers; these include determining which dissection method is more effective for learner learning. The pragmatic paradigm emphasizes finding solutions and making informed decisions based on what works best in the real world (Creswell and Creswell, 2018; Shannon-Baker, 2016). The findings of my study directly inform teaching practices and potentially lead to changes in curriculum or resource allocation. Pragmatism values research that has real-world consequences and can be applied to improve educational outcomes (Kivunja and Kuyini, 2017; Lee et al., 2006).

The pragmatic paradigm is best suited for this study as it aims to compare the effectiveness of hands-on dissections and ICT simulated dissections using both qualitative and quantitative data. The quantitative data includes the comparison of the marks obtained in the pre-dissection test to those obtained in the post-dissection test to determine the improvement in understanding that took place as a result of the dissections, as well as the numerical value of learners that indicated their chosen mode of dissection in the questionnaire. The qualitative aspects addressed by this study explore learner opinions, experiences, and reasons for their preferences, providing a deeper understanding of how each method impacts the learning and understanding of learners. This flexibility of this paradigm ensures that diverse perspectives and data sources are integrated to provide comprehensive insights (Bergman, 2020). The paradigm is particularly relevant for education research because it prioritizes practical solutions and contextually relevant frameworks (Feilzer, 2010; Biesta, 2020). By focusing on real-world implications, embracing multiple perspectives, and prioritizing problem-solving, the research can contribute to meaningful improvements in science education (Feilzer, 2010; Biesta, 2020).

3.2 Research Design and Approach

Research design is a comprehensive framework that guided me on how to go about my research (Scott and Morrison, 2007). The design enables investigators to pay attention to the manner in which they create research techniques compatible with the specific topic while setting up their scientific exploration to lead to success. The investigation process is known as the study design process (Shaw, 2022).

This research approach aimed to provide a guiding framework for how the research study should be conducted. This means that it includes an outline of the procedures that is used for data collection and an analysis that addresses research questions or test hypotheses. In order to conduct the study well, it should include a clearly defined research topic, an accurately designed plan for data collection, and a systematic process for evaluating and interpreting the findings (Creswell and Creswell, 2018; Garg, 2016).

The research approach helps navigate the complexities of a research study, describing the procedures to ensure an organized approach to data collection and analysis. This was done to ensure the validity and reliability of the findings (Bryman, 2016; Cohen, Manion, and Morrison, 2018). Furthermore, it contributed to the clarity and coherence of my study, making it easier for others to understand and replicate the research process. This, in turn, was important as it shaped the overall research design. It directs the selection of appropriate research methods, data collection techniques, etc., by aligning these elements with the research questions or hypotheses (Creswell and Plano Clark, 2021). Additionally, it enabled me to anticipate potential challenges and develop strategies to mitigate them, thereby enhancing the robustness of the study (Punch and Oancea, 2014).

3.2.1 Mixed Method Approach

This study utilizes a mixed-method approach; this approach can be defined as research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or program of inquiry (Fetters and Molina-Azorin, 2018). In my study, I have collected data based on the answers learners gave in the pre- and post-tests; I then used this data to draw inferences on how each mode of dissection is used to teach the mammalian heart at the grade 10 level. The use of the mixed-method approach can be justified as this study was utilized because it includes both an inductive reasoning approach and a deductive reasoning approach, as well as both qualitative and quantitative analysis.

The mixed-methods research design can provide two examples: Convergent Parallel Design and Explanatory Sequential Design. I simultaneously collected and analysed quantitative data (in my study, the quantitative data consists of the test scores and the number of learners that indicated their preferences regarding the type of dissection they used in the questionnaire) and qualitative data (in my study, the qualitative data consists of the open-ended questions in the questionnaire, observations, as well as question 19 of the post-dissection tests). I began with quantitative data collection, where I was able to compare their test scores in the pre-dissection test to their scores in the post-dissection test. With regards to the questionnaire, learners were asked to indicate whether they found hands-on dissections or simulated dissections more valuable with regards to different aspects. For example, learners were asked if they found hands-on dissections more effective or if they found simulated dissections more effective. Another example is that learners were asked if they preferred hands-on dissections or if they preferred simulated dissections. These questions in the questionnaire provided me with a numerical value that represented how many learners found hands-on dissections more effective and how many found simulated dissections more effective, as well as how many learners preferred hands-on dissections and how many learners preferred simulated dissections.

In terms of the qualitative aspects of my study, question 19 of the post-dissection test asked learners to mention two aspects about the heart that they did not know prior to conducting the dissection. This allowed me to gain a deeper insight into the specific aspects of the heart that were best observed in each mode of dissection. Another qualitative aspect that was observed was the progression in the way learners answered the questions in the pre-dissection test and in the post-dissection test, allowing me to understand how their knowledge improved, deteriorated, or remained the same after conducting the dissections. The third aspect that adds to the qualitative nature of my study was in the questionnaire. Learners were asked to explain their choices; for example, when the learners were asked if they found hands-on dissections more effective or if they found simulated dissections more effective, they were then required to explain what made their choice of dissection more effective. Another example is that learners were asked if they preferred hands-on dissections or if they preferred simulated dissections; they had to explain what aspects of their chosen mode of dissection it was that they preferred. These questions then allowed me to understand and draw conclusions on the perceptions and views of learners when conducting both methods of dissection. I was also able to observe the progression in the answers provided by the learners by comparing their pre-dissection test answers to their post-dissection test answers, allowing me to identify the trends and differences in the learners' understanding of the mammalian heart.

3.3 Methodological choices

This section addresses the research methods that I have considered for the comparative study on hands-on and simulated dissections in Grade 10 Life Sciences.

3.3.1 Qualitative Methods

The qualitative research method focuses on analysing words, phrases, common themes, and sentences instead of numerical data and statistical analysis. With regards to my study, qualitatively I am focused on the positive and negative responses that learners provide for each mode of dissection. This allowed me to help gain a deeper understanding of the implications of their perceptions and how this, in turn, impacts the learning that is taking place. Furthermore, I wanted to observe the changes in the manner in which learners answered the pre-dissection and post-dissection tests; this was done by comparing the answers that learners provided in the pre-dissection test to those that they provided in the post-dissection test in order to gauge how their understanding improved after they had conducted the dissection. By examining the responses of participants, I was able to employ a qualitative approach to seek to comprehend the underlying reasons and motivations that influence the understanding of the dissection, as well as how the understanding of the learners improved after having conducted the dissection (Atkinson, 2017). The quality of the answers that learners provided in the post-dissection test would either be an improvement in comparison to the answers provided by learners in the pre-dissection test; alternatively, it was possible that learners may not have changed their answers at all. Whichever the outcome, it allowed me to deduce if the simulated dissection or hands-on dissection improved their understanding of the concept of the mammalian heart. Another possible outcome would have been that the quality of the answers they provided would have deteriorated in the post-dissection test, which would have indicated a negative response to the dissections.

Qualitative research delves into the complications of human behaviour, beliefs, and interactions, offering valuable insights into complex social phenomena. This needs to be taken into consideration when teaching any topic (Stickler and Hampel, 2015). In this study, I utilized the questionnaire to assess learners' perceptions of the use of simulated and hands-on dissections, which taps into the aspects of human behaviour, pre-existing beliefs, as well as past interactions that they have had with simulated dissections or hands-on dissections. In the context of this study, the above-mentioned aspects influence learner engagement, focus, etc., and in turn influences their overall understanding of the topic.

3.3.2 Quantitative Methods

When it comes to the quantitative research approach, I considered numbers and statistics to measure the research topic, especially among a given set of populations (Wilson, 1996). Quantitative approaches always ensure that the usage of statistics is in a quantifiable way. The approach helped me to describe an event numerically or statistically to further analyse it for an outcome (Babones, 2016). The numerical aspect that has been assessed in my study takes into account the marks obtained by learners in the pre-dissection test in comparison to the marks obtained by learners in the post-dissection tests, and this is an indication of how statistically well the understanding of learners changed after they conducted the dissection. While the improvement of the standard of the answers that learners provided in each of their tests serves as a qualitative aspect, it can be quantified and thus is reflected in the marks obtained (the total marks obtained in the pre-dissection test and in the post-dissection test) can be compared to provide me with the overall numerical improvement in marks. The pre-dissection test before each test group conducted either the hands-on dissection or simulated dissection, and then the post-dissection test based on their respective dissection activities allowed me to observe and measure the knowledge acquisition and skill development that occurred.

As for the questionnaire, in terms of quantitative aspects, I was able to see the number of learners that posed a specific stance, which can be displayed as visual representations (pie charts).

3.4 Research Sample

Sampling is the procedure through which small samples are collected from the target population for research purposes. The sample units are drawn to understand their characteristics and features through a predetermined selection procedure. These components are also known as sample points or observations (Shively, 2011).

For this study, I utilized a sample from the target population of 20 Grade 10 Life Sciences learners in Gauteng Province. I specifically chose Grade 10 learners because this is the foundational year for the subject, where they are first exposed to detailed anatomical structures, particularly the mammalian heart.

The selected learners were from a South African public-school context. My study took place at the school where I work; however, the learners were from a class that I do not teach and have never taught. Participation in my study was completely voluntary. Since the learners were selected from my workplace, the sampling technique used was convenience and purposive sampling. This decision was based on the availability of resources required for my study and the ease of travel for both the learners and me (Gill, 2007). I opted to use learners from my school because it is a school of specialization and possesses all the necessary equipment and resources required for my study (Zirkel et al., 2015). Additionally, the school’s close proximity eliminated additional travel costs for both the learners and I. This aspect of my sampling constitutes convenience sampling, as it was based on accessibility and availability of participants and resources (Gill, 2007).

3.4.1 Sampling Method

For my study I utilized a two-stage sampling method, first learners were selected through convenience and purposive sampling, as the school had the resources required for my study and was easily accessible (Gill, 2007; Zirkel et al., 2015). The first sample consisted of 20 Grade 10 Life Sciences learners. All participants were volunteers from a class that I do not teach.

The reason for the methods of sampling used are explained below

3.4.1.1 Convenience Sampling

The first stage involved selecting 20 learners from the South African public school system using convenience sampling. This was done because:

The school where I work is within close proximity, eliminating additional travel expenses for both the learners and myself.

The school is a specialized institution equipped with all the necessary instruments and resources required for my research (Gill, 2007).

3.4.1.2 Random Sampling

By implementing this two-stage sampling process, I ensured that the study was both feasible and methodologically sound while maintaining fairness and accessibility for all participants.

In summary, the sample was taken from the school where I work; 20 learners were used on a voluntary basis from a class that I do not teach. These 20 learners were taught the theoretical lesson and wrote the pre-dissection test; they then were randomly assigned to either take part in the hands-on dissection (10 learners) or the simulated dissection (10 learners). They all then wrote the post-dissection test. They were then requested to answer the questionnaire, and 15 learners did so.

3.4.2 Sampling Procedure

My study sample consisted of 20 Grade 10 Life Sciences learners from a public secondary school in Gauteng Province. They were selected through a combination of convenience and purposive sampling.

Participation in my study was completely voluntary, with both learner assent and parental consent secured prior to inclusion. Once the sample was finalised, the twenty learners were randomly allocated into two equal groups of ten: one group conducted physical dissection of a cow's heart, while the other group conducted an ICT simulated dissection of the same content. After each group had completed their dissections, they then conducted the alternate method to ensure fairness of exposure.

Although all twenty participants completed both the pre- and post-tests, only fifteen learners chose to complete the questionnaire. This provided valuable reflection of learner perceptions and preferences.

3.5 Data Collection

The research study was carried out in a class where I do not usually teach; I first taught a theoretical lesson based on the mammalian heart to the entire class, and the whole class was given the pre-dissection test to answer according to what they had learned in the theoretical lesson. The pre-dissection tests were collected and kept safely. These tests allowed me to see the basis of what they understood about the heart before conducting any dissection. I then split the class into two random groups. The first group was sent to the physical dissection setup and dissected the cow's hearts, while the second group went to the devices setup and did a simulated dissection using the smartboard and their tablets. Both groups then returned to their seats, where they were then given a post-dissection test. The post-dissection tests were then collected and attached to the pre-dissection tests. The post-dissection test showed me the progression in answers when compared to the pre-dissection test. The learners then were given the opportunity to conduct the mode of dissection that they had not conducted, meaning that the learners that were part of the group that conducted the hands-on dissection would now conduct the simulated dissection and vice versa. This was to ensure that no learner was disadvantaged based on the mode of dissection they conducted and to ensure that no learner was unfairly advantaged or disadvantaged. The learners were then requested to answer a questionnaire based on their experiences, and of the 20 learners that took part thus far, only 15 answered the questionnaire. The questionnaire allowed me to better understand the learners' experiences, preferences, and reasons for their choices.

3.6 Data Analysis

The data analysis for this comparative study involves a multi-varied approach to accommodate both quantitative and qualitative data. The sample of grade 10 learners was first taught the theoretical lesson on the heart; thereafter, both groups of learners first answered the pre-test. One group then conducted the hands-on dissection, and the other group conducted the simulated dissection; they then both answered the post-dissection test. Both groups were then allowed to conduct the dissection that they had previously not partook in. For example, if a learner first conducted the hands-on dissection, they would now conduct the simulated dissection. This was done to ensure that the learners get exposed to both ways of dissecting to avoid disadvantaging either group. After both groups had done both types of dissections, the learners were then given the questionnaire, where they answered questions about their experience and also to determine their perceptions of these dissections.

3.6.1 Pre-dissection test

The pre-dissection test serves as a baseline after the theoretical lesson but before the intervention, from which I was able to observe the changes in the understanding of learners.

3.6.2 post-dissection test

The post-dissection test displayed the changes in the understanding of learners by allowing me to compare the quality of the answers that learners provided in the pre-dissection test, the purpose of which was to gain deeper insights into the trends that learners followed with regards to the depth and manner in which they answered the pre-dissection test and the post-dissection test. In terms of the numerical aspect of the dissection tests, I was then able to observe the changes in the marks obtained by learners before and after the dissections.

3.6.3 Questionnaire

This study has used both quantitative and qualitative questionnaires. The purpose of the quantitative aspects of the questionnaire was to gather numerical data on the learners' preferences and dislikes regarding each mode of dissection. The format I employed for this was that learners were asked to tick the method they preferred more between either hands-on dissections or simulated dissections as their answers. The data was then represented diagrammatically in a pie chart. In terms of the qualitative aspects of the questionnaire, the learners had to explain their choices as to why they picked that particular mode of dissection. I was also able to go beyond the surface of their perceptions of hands-on and simulated dissections by allowing for more open-ended answers with regards to their experiences using both modes of dissection.

3.7 Limitations of the study

My study had a relatively small sample of only 20 learners from the school that I work at. Although the findings provide useful indications, the small number of participants limits the generalisability of the results to the wider population of Grade 10 learners in South Africa.

The use of convenience sampling, based on accessibility and availability of resources, may have introduced bias. Although random assignment was applied when dividing learners into hands-on and ICT-simulated groups, the initial convenience sampling limits the representativeness of the sample.

Although all 20 learners participated in the tests and dissections, only 15 completed the questionnaire. This reduced the pool of qualitative data and may not fully capture the range of learner experiences and perspectives.

3.8 Ethical Considerations

This research involved human participation, as data was collected through the learners' involvement in the study. Due to the fact that I am a teacher at the school where I had conducted my research, I needed to ensure that no ethical concerns arose. In order to do so, I conducted the study with a class that I do not teach and have never taught.

To ensure that no learner was disadvantaged by participating or not participating in the study, all of the learners eventually received the same lesson at different times. Participation for all parts of the study was entirely voluntary, and learners could withdraw from the study at any time without any consequences. If a participant felt uncomfortable with any of the questions, they had the option not to respond; however, none of the questions were deemed sensitive to any group. Each participant received a participant information sheet detailing the study's expectations, and parental or guardian consent was required via a signed consent form, while learners signed an assent form to indicate their voluntary participation (Lonborg and Bowen, 2004).

Participants' identities were kept anonymous as much as possible throughout the study. Each learner was assigned a number from 1 to 20 to maintain confidentiality. However, anonymity was not feasible in all instances, such as during lesson instruction. In cases where anonymity was not possible, only my supervisor and I had access to participant identities. In the data presentation, pseudonyms (numbers 1–20) were used to further ensure anonymity and protect participants' privacy. All collected data was stored in an encrypted file and will be deleted five years after the completion of the research (Goodman and Carey, 2004).

To safeguard the emotional and mental well-being of participants, all questions avoided sensitive personal topics or invasive inquiries. Participants were allowed to withdraw from the study at any point without repercussions if they felt uncomfortable.

Ethical clearance for the study was obtained from the WSoE Ethics Committee, and the clearance certificate is attached as Appendix 5.

3.7 Chapter Summary

This chapter expanded on the choices that I made with regards to the research methodologies of my study; it further explains the method of sampling my research participants, as well as the data collection procedures and data analysis processes that I employed.

Chapter 4: <u>Data analysis, presentation and interpretation</u>

4.0 Introduction

This chapter aims to analyse the data that I have collected through the questionnaire and the pre- and post-dissection tests to explore the specific challenges and opportunities that hands-on and simulated dissections have when teaching the human heart in grade 10 life sciences.

Each questionnaire participant was assigned a number (1 - 20), which acted as a representative code, so I could organize their responses and distinguish between the participants. Learners 1 - 10 conducted the simulated dissection and learners 11 - 20 conducted the hands-on dissection. Of the 20 participants of the dissections only 15 then answered the questionnaire as it was also on a voluntary basis.

To organize the themes around which the study is structured I assigned the themes using the letters a - d and I assigned the subthemes using the Roman numerals i - v, which were derived from the research questions.

The themes and subthemes are aligned with the research questions as follows:

i. To what extent do information and communication technology dissections conducted through simulations influence the understanding of the mammalian heart by Grade 10 learners?

ii. To what extent do traditional hands-on dissections influence the understanding of the mammalian heart by Grade 10 learners?

iii. To what extent did the dissections not influence the understanding of the mammalian heart by grade 10 learners?

iv. What are the challenges and opportunities of the use of ICT-based simulations of dissections and those of traditional hands-on dissections in Grade 10 Life Sciences?

Opportunities and challenges of ICT simulations in Life Sciences dissections

The opportunities and challenges associated with ICT-simulated dissections are listed below:

Opportunities of ICT simulated dissections

1. Cost-effectiveness of ICT simulations
2. Logistical Considerations
3. Skill Development
4. Ethical and Humanitarian Considerations
5. Safety

Challenges of ICT simulated dissections

6. Lack of Tactile Engagement in ICT Simulations
7. Technological Dependency and Accessibility Issues
8. Oversimplification of Anatomical Structures

Opportunities and Challenges of Hands-on Dissections in Life Sciences Education

The opportunities and challenges associated with hands-on dissections are listed below:

Opportunities for Hands-on Dissections

1. Enhanced Spatial Awareness and Understanding of Anatomy
2. Development of Fine Motor and Dissection Skills
3. Improved Retention and Recall of Information

Challenges of Hands-on Dissections

4. Ethical and Humanitarian Concerns
5. Safety Risks and Hazardous Materials
6. Logistical and Resource Constraints
7. Inconsistency in Specimen Quality

8. Time Constraints in Curriculum

v. <u>What are the views of learners about the effectiveness of ICT simulated dissections in comparison with hands-on dissection in Life Sciences education at Grade 10?</u>

The following aspects influence the perceptions of learners about the effectiveness of ICT simulations in comparison with hands-on dissections:

1. Learner preference
2. Learners' view regarding which mode of dissection is more effective
3. Learner understanding
4. Learners' overall view as to which mode of dissection is most superior

From the data collected in the questionnaire, I was able to deduce that both modes of dissection had aided and hindered learning in different ways and it was dependent on numerous factors which I will discuss in the findings.

4.1 Result and Discussion of Findings

<u>i. To what extent do information and communication technology dissections conducted through simulations influence the understanding of the mammalian heart by Grade 10 learners?</u>

The following specific questions showed trends of great improvement in the understanding as a result of conducting the simulated dissection in comparison with the hands-on dissection:

Questions 5, 6, 8, 10,17 and 19

<u>Question 5</u>

This question required learners to identify the structure that separates the right and left sides of the heart.

From the overall 20 learners that took part in the dissections only a total of 3 learners correctly identified the septum in the pre-dissection test. As for the post-dissection test from the 10 learners who conducted the simulated dissection 9 learners were able to identify that the septum separates the two sides of the heart, this indicates that the labelling of structures on the simulated dissection was greatly beneficial to learning and greatly improved the learners understanding. On the other hand, in the post-dissection test only 3 of the 10 learners who conducted the hands-on dissection were able to identify the septum, from 7 learners 5 learners chose option B (Atrium), and the remaining 2 learners chose option A (Ventricle). The main reason for their confusion was because the cow's hearts used in the hands-on dissection and what they had learned on 2-D diagrams did not look the same in terms of view and colour so, they were unable to see the septum and as a result were unable to link it's the structure to its function of separating the right and left side of the heart.

Question 6

This question asked learners to name the structure that acts like doors that control blood flow in the heart. The results from this question show a similar trend to that of question 5, from the 10 learners who conducted the simulated dissection 4 learners correctly answered that the valves act like doors in the pre-dissection test and in the post-dissection test all 10 were able to identify the valves, I concluded that this favourable outcome was as a result of the simulation displaying a beating heart model of the heart with labels.

As for those who conducted the hands-on dissection in the pre-dissection test 4 learners correctly stated the valves and after the dissection only 5 learners answered correctly, this means that only one learner's understanding of the concept improved after the dissection, which I attribute to the fact that when one compares with what they would have seen in the diagrams, it's difficult to equate it to real life and real tissue of the heart and the blood in the organ also covered some parts like the valves so it was difficult to see. With regards to the 5 learners who answered incorrectly all 5 chose option D (chambers), this indicates that they were unable to visualize the difference between the chambers and the valves.

Question 8

This question required learners to label a diagram of the heart on the worksheet provided.

This question consists of 6 labels as follows:

Label 1: Pulmonary artery

Label 2: Superior Vena Cava

Label 3: Pulmonary Vein

Label 4: Right Atrium

Label 5: Left Ventricle

Label 6: Pericardium/ Fat

Labels 1, 2 and 3

In the pre-dissection test all 20 of the learners labelled the structure correctly and the same applied to the post-dissection test.

Label 4

Of the 10 learners who took part in the simulated dissection only 7 initially answered correctly in the pre-dissection test, 2 learners did not answer the question, and 1 learner labelled the structure incorrectly, in the post-dissection test 8 learners correctly labelled the structure and the same 2 learners did not answer the post dissection - test.

With regards to the learners that conducted the hands-on dissection 8 learners answered correctly in the pre-dissection test and 9 of them correctly labelled the structure in the post dissection test, the remaining 1 learner did not answer the question.

Label 5

From the learners that conducted the simulated dissection, 2 learners answered the pre-dissection test correctly and in the post-dissection test 7 learners labelled the structures correctly, this indicates that the simulated dissection improved the identification of the left ventricle a great deal.

In the pre-dissection test, 3 of the learners who conducted the hand-dissection labelled these structures correctly, however in the post-dissection test only 5 learners answered correctly, and the remaining 5 learners mixed up labels 5 and 6, this was because the hands-on dissection the structures seemed very similar, I will discuss question 6 in isolation below.

Label 6

This question required learners to identify the pericardium, however, it would have also been correct if learners identified the structure as Fat tissue.

With regards to the pre-dissection test for the simulated dissection, 2 learners initially answered the question correctly, and when we compare this to the 8 learners that answered it correctly in the post-dissection test we can see that the simulated dissection improved the learner's understanding.

Question 10

This question required learners to draw arrows to show the direction of the flow of blood through the heart. In the pre-dissection test a total of 2 learners correctly answered this question as it was a very theoretical question but once the learners conducted the dissection, from those who conducted the simulated dissection 8 learners correctly answered this question, as it was easier to visualize the movement of blood as the simulation displayed a beating heart model that demonstrated the flow of blood. With regards to the hands-on dissection 3 learners correctly answered the post-dissection test for this question, this demonstrated minimal improvement, this could be due to the fact that in the hands-on dissection there was no demonstration of how the blood flows and the direction which it takes.

Question 17

Question 17 asked for a visual difference between the tricuspid valve and the bicuspid valve.

The learners that conducted the simulated dissection were able to see the visual differences between the two valves more easily, in the pre - dissection test 6 learners answered this question correctly and in the post-dissection test 9 answered correctly. The one learner who still answered incorrectly stated that the bicuspid valve is between the right atrium and right ventricle which seems to have been a mistake when recalling memory. With regards to the hands-on dissection in both the pre-dissection and post-dissection tests 5 learners answered this correctly, it was difficult to see each valve individually on the cow’s heart.

Question 19

The following information addresses question 19 as observed by the learners who conducted the simulated dissection. This question asked learners to explain two things about the heart now know that they previously did not.

The answers that learners provided are summarised below:

1. The heart has different types of valves.
2. The opening and closing of the valves are the beating sounds of the heart.
3. Valves prevent backflow of blood.
4. The way that blood flows through the heart.
5. The heart is situated in the middle of the chest.
6. Oxygenated and deoxygenated blood never mix.

ii. To what extent do traditional hands-on dissections influence the understanding of the mammalian heart by Grade 10 learners?

The following specific questions showed trends of great improvement in the understanding as a result of conducting the hands-on dissection in comparison to the simulated dissection:

Question 11

Question 12

Question 13

Question 15

Question 19

Question 11

This question asked the learners to describe the differences in the thickness of the ventricles, as well as the structural function this holds. In the pre-dissection test 1 learner correctly answered this question, from those who conducted the simulated dissection only 3 learners answered the post-dissection test, and their understanding of the concept was not greatly improved. The trend seen here can be due to the fact that with the simulated dissection the difference in thickness was not very visible. With the learners that conducted the hands-on dissection 1 learner had initially answered the question correctly in the pre-dissection test, however, 9 learners answered correctly in the post-dissection test this showed a deeper understanding as a result of the hands-on dissection. The remaining 1 learner stated that “the right ventricle has thicker walls because it requires more muscle power”.

Question 12

This question required learners to draw in the difference in thickness. From the learners that conducted the simulated dissection 3 learners answered this question correctly in both the pre - dissection and post-dissection tests, the remaining 7 learners skipped the question entirely. With the learners that conducted the hands-on dissection, 3 learners answered the pre-dissection correctly and in the post-dissection test 9 learners answered the question correctly, this signifies that the hands-on dissection improved the understanding of the learners, the hand - on dissection allows learners to feel and touch the tissue therefore allowing them to physically feel the difference in thickness of the ventricles. It was further evident that the learners that answered question 11 wrong also answered question 12 wrong as the second question built on the first one.

Question 13

Question 13 asked learners to describe the texture of the heart. Learners that conducted the simulated dissection, struggled to answer this question, and the same 2 learners that answered it correctly in the pre-dissection test did so in the post-dissection test. It can be assumed that as the learners that conducted the simulated dissections could not feel the difference in texture it makes sense that they were unable to answer this question. 1 of the learners that conducted the hands-on dissection answered this question correctly in the pre-dissection test and this improved to 9 learners in the post-dissection test, this trend shows that the understanding of the learners greatly improved as they could touch and feel the texture of the heart.

Question 15

This question required learners to describe the location of the fat found on the heart as well as the purpose that it poses. In the pre-dissection test 4 of the learners who conducted the simulated dissection could describe its location and this number remained the same in the post-dissection test, many learners simply answered along the lines of “around the heart” or “on the outside of the heart” without being specific the description of the purpose of the fat was fairly well answered in the pre-dissection and post-dissection tests 8 learners answered this sub-question correctly. This indicates that although the learners understood the theory they were unable to see the fat as it was not labelled on the diagram. As for the learners who conducted the hands-on dissection, in the pre - dissection test 3 learners answered the location of the heart correctly and 8 answered the post-dissection test correctly. 8 learners answered the purpose of the fat correctly in the pre and post-dissection tests. The remaining two learners that answered incorrectly did not specify the exact location of the fat rather they said it was around the heart.

<u>Question 19</u>

Question 19 as observed by the learners who conducted the hands-on dissection

This question asked learners to explain two things about the heart that they now know that they previously did not.

1. The human heart is smaller than a cow’s heart.
2. The human heart is the size of a fist.
3. The walls of the aorta are much thicker than that of the pulmonary vein.
4. There is fat surrounding the heart.
5. There is a layer of pericardium.

4.1.0 Presentation of results

The study's findings are precisely described throughout this section. The data was rephrased using appropriate tables together with relevant graphs and charts when possible.

4.1.1 Results obtained from the pre - dissection test

This section presents the findings from the pre-dissection test administered to Grade 10 Life Sciences learners before engaging in either simulated or hands-on dissection activities. The test aimed to assess baseline understanding of mammalian heart anatomy. These initial results provide a foundation for evaluating the impact of the subsequent dissection methods on learners' comprehension.

Overall Performance

The pre- dissection test results revealed a mixed level of prior knowledge regarding the mammalian heart. While certain fundamental concepts were well - understood by the majority of learners, significant gaps existed in areas requiring more detailed anatomical knowledge and conceptual understanding.

Detailed Analysis by Question

The results for each question are summarized in Table 1 below.

Table 1: Pre-dissection Test Results by Question (n=20)

Question Number	Question Description	Number of Correct Answers	Number of Incorrect Answers	Number of No Response
1	Number of Chambers in the Heart	20	0	0
2	Name of the movement of blood through the body.	19	1	0
3	Process causing the beating sound of the heart	19	1	0
4	Substances transported by the circulatory system.	9	11	0

5	Structure separating the right and left sides of the heart	3	17	0
6	Structure acting as doors controlling blood flow	4	16	0
7	Tubes carrying blood back to the heart	18	2	0
8 (Label 1)	Labelling diagram of the heart (pulmonary artery)	20	0	0
8 (Label 2)	Labelling diagram of the heart (superior vena cava)	20	0	0
8 (Label 3)	Labelling diagram of the heart (pulmonary vein)	20	0	0
8 (Label 4)	Labelling diagram of the heart (structure 4)	15	1	4
8 (Label 5)	Labelling diagram of the heart (structure 5)	5	15	0
8 (Label 6)	Labelling diagram of the heart (structure 6)	5	15	0

9	Draw where to dissect the heart	7	13	0
10	Draw arrows showing blood flow direction	2	18	0
11	Describe differences in ventricle thickness and function	1	19	0
12	Draw differences in ventricle thickness.	6	14	0
13	Describe the texture of the heart	3	17	0
14	Deduction about the function of the pericardium	18	2	0
15	Describe location and purpose of fat on the heart	7	13	0
16	Describe aorta's adaptation to its function	16	4	0
17	Visual difference between tricuspid and bicuspid valve	6	14	0

19	Explain two new things about the heart	N/ A	N/ A	N/ A

*Note: Question 19 was open-ended and not scored for correctness.

Labels 4,5 and 6 will need to specify the structure labelled.

Table 2: Means achieved by learners in the pre-dissection test and the post-dissection test for both hand-on dissection and simulated dissections

	Mark achieved out of 30	Percentage achieved (%)
Mean achieved by learners in the pre- dissection test	14.15	47.17%
Mean achieved by learners in the in the post- dissection test	17.85	59.5%

The overall percentage increase was 26.14%.

Table 3: Means achieved by learners who conducted the hands-on dissection

	Mark achieved out of 30	Percentage achieved (%)
Mean achieved in the pre-dissection test by learners conducting the hands-on dissection	16.2	54%
Mean achieved in the post-dissection test by learners conducting the hands-on dissection	20	66.67%

Table 4: Means achieved by learners who conducted the ICT simulated dissection

	Mark achieved out of 30	Percentage achieved (%)
Mean achieved in the pre-dissection test by learners conducting the ICT simulated dissection	11.9	39.67%
Mean achieved in the post-dissection test by learners conducting the ICT simulated dissection	15.7	52.33%

Table 5: Percentage increase for hands-on dissections and for simulated dissections

	Percentage increase between the pre and post dissection tests (%)
Hands-on dissection	23.46%
Simulated dissection	31.91%

There was a notable increase in understanding by learners regardless of the mode of dissection that they used, this indicates the value of dissections in Life Sciences education.

With regards to the hands-on dissection, in the pre-dissection test learners achieved more than 16.2 out of 30 (or 54%) while in the post-dissection test, the same learners achieved 20 out of 30 (or 66.67%). This shows a 23.46% percentage increase.

In terms of the ICT simulated dissection in the pre-dissection test, learners achieved d a mean of 11.9 out of 30 (or 39.67%) while in the post-dissection test, the same learners achieved 15.7 out of 30 (or 52.33%). This shows a 39.91% percentage increase.

Incorrect Understandings and Common Misconceptions

Several prevalent misconceptions were identified through the pre-dissection test:

-Heart Anatomy: A significant number of learners struggled to identify key internal structures of the heart, particularly the septum (Question 5).

-Blood Flow: Understanding of blood flow through the heart was weak, as demonstrated by the low number of correct responses in Question 10.

- Ventricle Thickness: Very few learners demonstrated awareness of the differences in ventricle wall thickness and the functional significance of these differences (Question 11).

- Fat Deposits: Many learners were unable to accurately describe the location and/ or purpose of fat deposits on the heart (Question 15).

- Circulatory System: There seems to be some confusion regarding the substances the blood carries in the circulatory system (Question 4), learners seem to think the blood only transports oxygen and not the other gasses and nutrients.

The results of the pre-dissection test displayed a mixed baseline of the understanding of the learners, most learners were able to answer the simple question that required them to recall facts easily such as question 1 which asked for the number of chambers in the heart and question 14 which asked the learners about the role of the pericardium, this suggested that the theoretical lesson established their basic knowledge of the content well, However, when dealing with more complex questions that addressed spatial reasoning or functional understanding most learners were unable to answer the question correctly, such as in the case of question 5 which asked to identify the septum or question10 that asked to draw the flow of blood through the heart .

Quantitative analysis: The average achieved in the pre-dissection test was 14.15/30 (47.17%), this indicated that less than half of the content was understood before the dissections. Although the groups were selected at random the hands-on dissection group performed slightly higher at baseline (54%) compared to those in the simulated group (39.67%). Indicating a difference in prior knowledge that the learners had begun with, which was important to account for when interpreting learning improvement.

Qualitative interpretation: in the questionnaire there was some indication that many learners felt uncertain about internal heart structures before any dissection took place. Some learners indicated that they could recall “names from the textbook,” they “could not imagine where everything was inside the heart.” This makes clear indications that concrete or visual experiences were needed in order to fully grasp the topic and to make the theoretical knowledge less abstract.

4.1.2 Results obtained from the post-dissection test

This analysis examines which modalities - hands-on versus simulated heart dissections - best allow Grade 10 learners to improve their understanding of the mammalian heart through their pre- and post-dissection scores by assessing knowledge gains, persistent misconceptions, and overall learning trends. In the study, learners were divided into two groups: One group first performed a simulated dissection and the second group performed a hands-on dissection of cow hearts, followed by a crossover between groups to experience the alternative method. This post compares the two in detail, as well as the effects the two methods have on learners.

Conceptual Understanding Advances

The improvements in conceptual understanding following exposure to both dissection methods were evident in the study, but these improvements differed in areas. In Simulated Dissections, learners showed marked improvement in internal structure identification such as septum and valves. Indeed, the architecture of the simulation's clear informative labelling of visual representations like the beating heart model prompted learners to relate structure to function. For example, in the pre-dissection test, only 3 out of 20 learners were able to correctly identify the septum, but the count rose to 9 out of 10 in that group post - simulation. In addition, the number of learners correctly sketching the direction of blood flow through the heart significantly increased.

An animated visualization of the blood flow part of the simulation in particular facilitated this understanding, as indicated by a jump in the number of learners (post-dissection test) drawing arrows to show the blood flow in the heart from 2 to 8 learners. Finally, actual differences visually in the Bicuspid and Tricuspid valves that are not that clear with a simulated dissection were more evident when 3 learners improved in the post-dissection test.

On the other hand, hands-on dissections showed a significant improvement in knowledge of ventricular structure and function. This improvement was directly attributed to the tactile sensation of palpating the differences in texture and thickness of the ventricles. Hands-on experience increased the number of learners from 1 learner answering correctly in the pre-dissections to 9 learners answering correctly in the post-dissection test.

After engaging in the hands-on part of the dissection, learners were also better able to describe the texture of the heart and the location of fat deposits; physical interaction with the heart during dissection enabled learners to see these features directly, where they were less pronounced or missing in simulation. In addition, the accuracy of answering the texture question improved (Pre- dissection test- only 1 learner answered correctly; post-dissection test- 9 learners answered correctly). Last, because of being physical, hands-on dissection enabled the learners to grasp the shape and size of the real mammalian hearts, which was less prevalent in the simulated dissection.

<u>Cryptic Patterns and Persistent Errors</u>

However, this study also showed some misunderstandings and restrictions remained following both dissection methods. Heart Knowledge Questions The questions related to basic knowledge of the heart including the number of chambers, the function of the pericardium, and blood circulation did not demonstrate much or any improvement. This seems to mean that the pre- dissection theoretical lesson was enough for these concepts and that the dissections were not majorly reinforcing for these concepts.

<u>Limitations of Hands-on Specimen Quality</u>

The study highlighted a significant drawback of using butchery-sourced hearts: the hearts were often pre-cut, hindering learners' ability to visualize internal structures intact. This was what contributed to the hands-on group not doing better than the simulation group identifying areas like the septum and valves. It also influenced how they drew the line of dissection. The abstract circulatory system concepts that remained difficult even with successful methodological dissection (for example, what it is that the circulatory system transports specifically) indicate that in addition to methodological dissection, targeted instruction is needed to target such abstraction misconceptions. Although accurate representations, the visual differences in the valves were still hard for 1 learner to grasp through simulated dissection.

<u>Comparison of Dissection Techniques</u>

Simulated Dissections advantages include clear visualization and labelling as well as the ability to simulate dynamic processes (e.g., blood flow); this modality illustrates spatial relationships and structures well. The simulated dissection offered some great benefits but did come with some limitations including no tactile experience, a potential reliance on technology (such as Wi-Fi), and less engagement for some learners. Its strengths include the tactile aspect of learning, better understanding of physical properties (such as texture and thickness), and increased engagement for most learners in hands-on dissections; while its weaknesses include the issues of specimen quality, ethics, safety, and messiness.

<u>iii. To what extent did the dissections not influence the understanding of the mammalian heart by grade 10 learners?</u>

Specific questions showed no trends of improved understanding as a result of conducting either mode of dissection.

Question 1

Question 2

Question 3

Question 4

Question 7

Question 9

Question 14

Question 16

Question 1

The first question in the tests was a lower-order question asking about the number of chambers in the heart. All 20 learners correctly answered this question in both the pre-dissection test and the post-dissection test. It was noted that learner number 17 provided more detail to the answer in the post-dissection test, he/ she answered that there are “4 chambers in the heart” in the pre-dissection test and later answered that there are “4 hollow chambers in the heart” in the post dissection test, showing that knowledge was improved through the hands-on dissection.

Question 2

This question asked learners to name the movement of blood through the body and 19 of the 20 learners correctly answered this question in the pre- dissection test and all 20 learners answered the question correctly in the post-dissection test.

Learner number 4 was the learner who incorrectly answered the question in the pre-dissection test by answering “cardiac cycle” he/ she later corrected themselves in the post-dissection test, however, this was likely not as a result of the mode of dissection but rather of the terminology used when the dissection was conducted.

Question 3

Question 3 asked learners what process causes the beating sound of the heart. All 10 of the learners who conducted the simulated dissection correctly answered this in the pre-dissection test and in the post-dissection test. Of the 10 learners who conducted the hands-on dissection 9 learners correctly answered this question.

Question 4

Required learners to list the substances that are transported by the circulatory system. From the 10 learners conducted, the simulated dissection 4 learners correctly answered question 4 in the pre- and post-dissection tests the remaining 6 answered incorrectly in both tests. Of the 10 learners who conducted the hands-on dissection 5 learners correctly answered this question the remaining 5 learners answered this question incorrectly in both tests. The reason for this seems to stem from the misconception that only oxygen is transported around the body by blood when in reality oxygen, carbon - dioxide, and nutrients are transported by the circulatory system. This misconception was not a result of the mode of dissection used.

Question 7

Question 7 asked learners which tube carries blood back to the heart. In the pre - dissection test 18 of the 20 learners answered veins correctly, and in the post - dissection all 20 learners answered correctly, this can be deemed as a result of the specialized terminology used when the dissection was conducted.

Question 9

This question required learners to draw a dotted line where they would have dissected the heart. The number of learners that conducted the simulated dissection improved from 4 correct answers in the pre-dissection test to 5 correct answers in the post-dissection test, this shows minimal improvements in the understanding of the concept.

With regards to the hands-on dissection, 3 learners drew the dotted line in the correct place in the pre-dissection test and this number remained the same in the post-dissection test, this indicates that no improvement took place because the cow's hearts were already cut open by the butcher although it is possible to get uncut hearts it is often very difficult.

Question 14

Question 14 required learners to make a deduction about the function of the pericardium.

This question was answered relativity well by both sample groups in the pre and post-dissection test. In the pre - dissection tests a total of 18 learners answered the question correctly and this number remained the same in the post-dissection test.

Question 16

This question required the learner to describe how the aorta is specifically adapted to its function.

This was a theoretical question that most learners answered correctly in the pre-section test 16 learners answered correctly and in the post-dissection test 17 learners answered correctly.

The post dissection test results displayed a notable improvement in the learns understanding of the mammalian heart, the questions that showed improvements were different depending on which mode of dissection was used.

Quantitative analysis: Overall, learners' average increased from 14.15/30 (47.17%) in the pre-test to 17.85/30 (59.5%) in the post-test, reflecting an average gain of 26.14%. Learners in the group that conducted the hands-on dissection improved from 16.2/30 (54%) to 20/30 (66.67%), while the group that conducted the simulated dissection improved from 11.9/30 (39.67%) to 15.7/30 (52.33%). This meant that although the simulated group started lower, they showed a larger relative improvement (31.91% increase compared to 23.46% for the hands-on group).

Qualitative interpretation: We are able to understand why this patterns were seen through the feedback that learners gave. Learners who conducted the simulated dissection mentioned that "the beating heart model with labels made it easier to see blood flow" and that structures such as valves were "clearer than in the cow heart." This aligns with the quantitative results that suggested that the simulated dissections produced stronger improvements in identification of the septum and valves. On the other hand, learners that conducted the hands-on dissection mentioned that they "could feel how thick the ventricle walls were" and "see the fat around the heart," supporting the test data showing greater improvement in questions requiring recognition of texture, thickness, and fat deposits.

4.1.3 Results obtained from the questionnaire

With regards to the questionnaire, it was on a completely voluntary basis, therefore of the whole group that took part in the dissections only 15 learners took part in the questionnaire but at this point, both groups of learners conducted both methods of dissection and therefore were able to comment on the hands-on dissection and simulated dissection.

As such, overall, the majority of learners preferred the hands-on dissection and found it more effective as it was interactive and tangible. A few learners chose the simulation for ethical reasons (to avoid harming animals) and squeamishness toward real organs.

Below I have discussed the answers that learners have provided to the questions included in the questionnaire:

<u>The mode of dissection that learners found to be most effective</u>

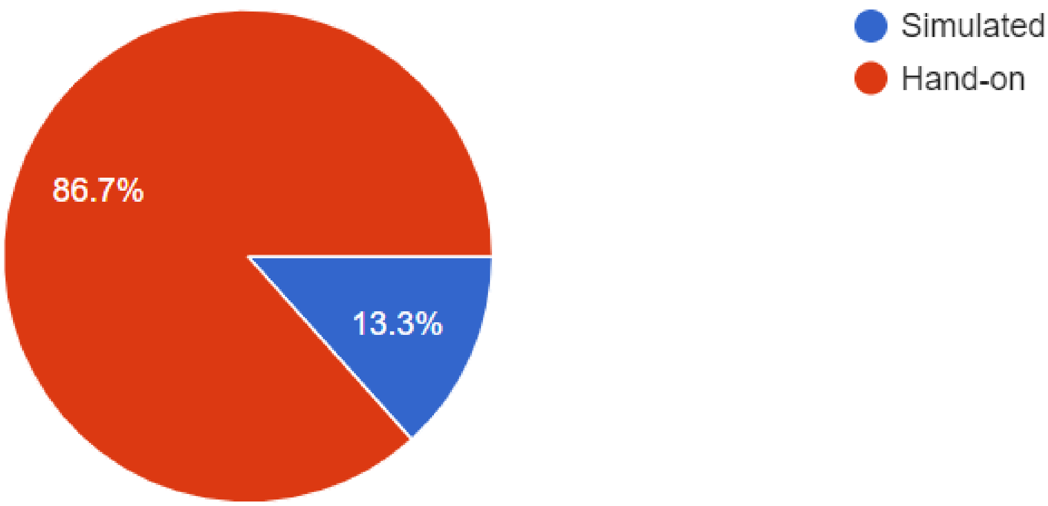


Figure 1: Pie chart depicting learner views as to which mode of dissection is most effective

Of the 15 learners that partook in this questionnaire,13 were of the stance that hands-on dissections have more value and effectiveness when being taught the topic of the human heart.

Two learners stated that the simulated dissection was more effective, their views were as follows:

Learner number 15's reasoning for this was that the simulation allowed the learners to view each chamber in isolation, it also provided labels for each part as they dissected the heart, making it a more meaningful experience.

Learner number 12 was of a similar opinion as he/ she found it easier to distinguish between the different structures by using the simulations and found that as the cow's heart was partially cut already they did not gain the full experience of dissecting it, this made it more difficult to see each structure, it is rare and difficult for learners to get uncut hearts as butchers are required to partially cut the heart before sale.

The remaining 13 learners viewed the hands-on dissection as more effective for the following reasons:

It allowed for a closer interaction with the heart.

It was simpler to recall the different components and structures of the heart as the learners actively dissected the physical heart and in turn, this made it easier to associate the different structures with their function as well as how the structures are interrelated.

It was also found that the simulated dissection relied on Wi-Fi and technology making it unpredictable.

The mode of dissection that learners preferred

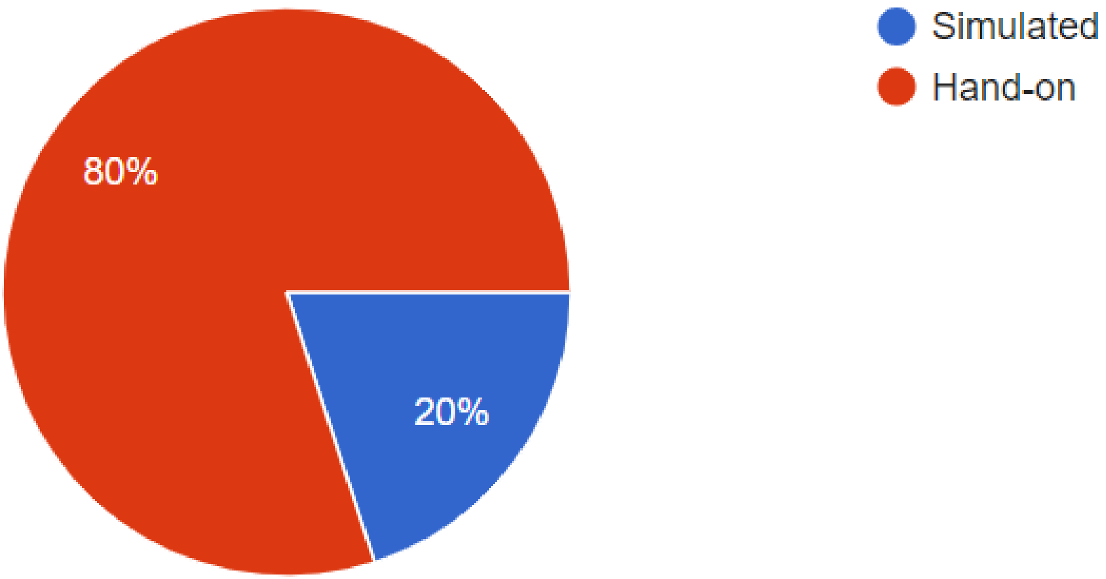


Figure 2: Pie chart depicting the percentage of learners that preferred each mode of dissection

The views of the 3 learners who preferred the simulated dissection are as follows:

Learner number 3 took an empathetic stance and stated that using a simulation is more humane as it does not require a real cow's heart.

Learners 12 and 14 both stated that they preferred not working with the actual organ as they did not enjoy the smells and were squeamish.

12 of the 15 learners preferred the hands-on dissection, their reasoning is summarised below:

The hands-on dissection granted physical manipulation with the organ making it more engaging and interactive.

Several learners found it enjoyable as they were able to learn the skills associated with dissection.

It is easier to recall the hands-on dissection compared to a simulation.

Touching the organ allowed learners to feel the texture and thickness of the heart.

<u>The mode of dissection that improved learners' understanding of the heart</u>

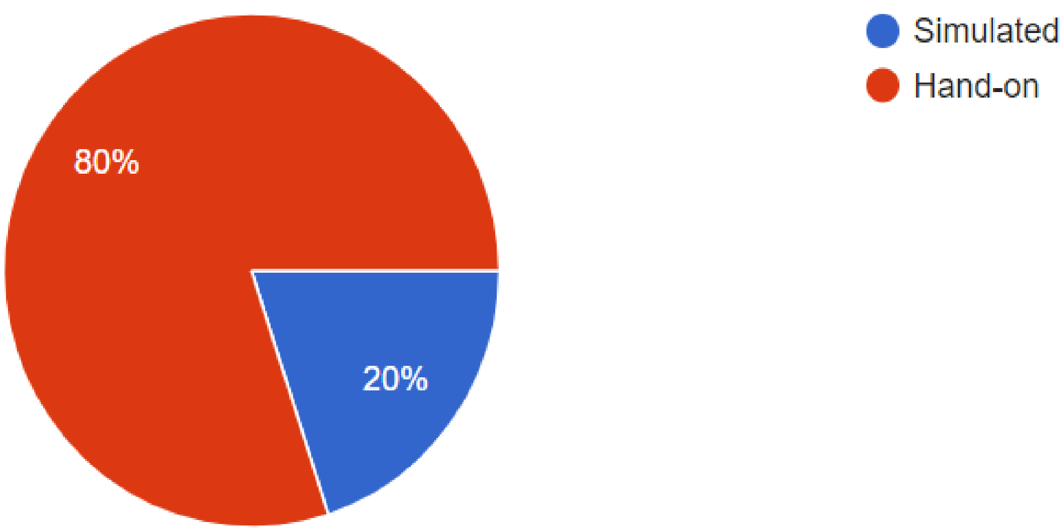


Figure 3: Pie chart demonstrating the percentage of learners who found hands-on dissections to improve their understanding of the topic in comparison to the percentage of learners who found dissections to improve their understanding of the topic

However, despite 13 learners finding hands-on dissections more effective learners only 12 found that their understanding of the topic was improved by the hands-on dissection.

The learner who varied from the rest of the sample stated that although he/ she found the hands-on more effective as it was not reliant on technology or Wi-Fi he/she that the labels on the simulated dissection allowed him/ her to observe the different structures and their roles more easily and as a result t, his improved his/ her understanding of the topic.

The mode of dissection that learners enjoyed participating in more

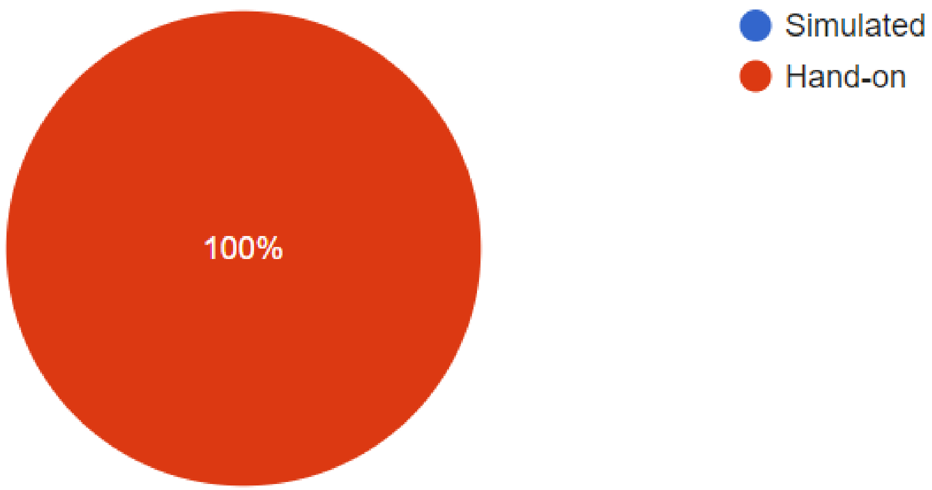


Figure 4: Pie chart depicting the dissection that learners enjoyed more

In terms of enjoyment of their participation, all the learners (15) enjoyed the hands-on dissection.

The mode of dissection that learners found to have developed their skills most

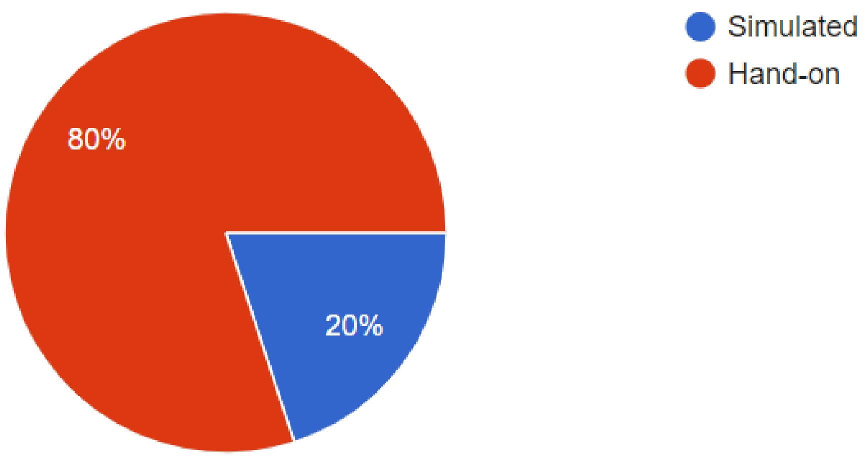


Figure 5: Pie chart depicting which mode of dissection taught learners the most skills

3 learners found that simulated dissections taught them more skills, these skills include:

- Using ICT devices to set up a simulated dissection
- How to use more equipment for its purpose as the simulation would not allow you to use the wrong equipment for any other purpose except its function
- Interpreting simulations
- Comparing simulations to real life

On the other hand, 12 of the 15 learners who took part in the questionnaire found that hands-on dissections equipped them with more skills, these skills are listed below:

The physical cutting/ dissecting of the heart (i.e. to dissect, how to use a scalpel, precision).

- Working with other group members.
- How to use equipment safely.
- The mode of dissection that learners found to be most superior overall

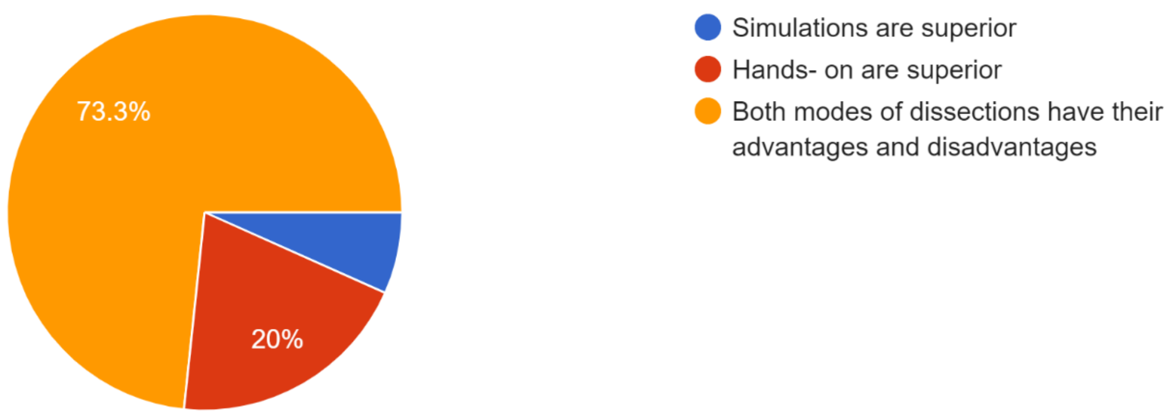


Figure 6: Pie chart depicting which mode of dissection is most superior overall

1 learner was of the stance that simulated dissections are superior overall, in his/ her view, the simulation did not harm any animals. There was also no wastage of food/ meat and there was no blood or smells in the simulated

dissection. He/ she also stated that simulated dissections are the safer option as there is no risk of getting cut/ hurt.

3 learners thought that hands-on dissections are the superior mode of dissection, for the following reasons:

- Real-life engagement with her heart makes the theoretical lesson more tangible and therefore easier to remember.
- It allowed for a closer examination of the organ.
- Hands-on dissection is more active participation in comparison to a simulated dissection.

The remaining 11 learners acknowledged that both modes of dissection have benefits and limitations, this group of the sample further expressed that a combination of both methods of dissection allowed them to gain a greater understanding of the topic.

The following reasons were provided by learners:

- The structures were clearer and more visible on the simulated dissection.
- It was easier to identify the different structures with the labels on the simulation.
- When using the simulation was no touching of blood or tissue and there were no smells.
- The simulation allowed learners to observe a beating heart and to watch the blood flow through the heart.
- Simulations provided a 2 - dimensional and 3 - dimensional view of the heart.
- It is illegal for butchers to sell animal hearts without cutting them, this means that some hearts were already cut open, and some of the cuts went through important structures making them unidentifiable.
- The hands-on dissections made it more difficult to identify structures on the heart

- It was not possible to provide every learner with their own heart to dissect this means that not every learner will dissect/ cut.
- Hands-on dissections allowed learners who were considering careers in the health science field to observe if they would be able to do so.
- Hands-on dissections provided active participation making it easier to remember.

From the questionnaire I was able to gain qualitative insights into learners' views of the effectiveness, challenges, and opportunities of each dissection mode. Of the 15 learners who completed the questionnaire, the majority expressed a preference for hands-on dissections, though a minority valued simulations for ethical reasons and due to the fact that the simulated dissections were more clear.

Quantitative overview:

Effectiveness: 13 learners indicated that hands-on dissections were more effective, while 2 favoured simulations.

Preference: 12 learners preferred hands-on dissections, while 3 preferred simulations.

Enjoyment: All 15 learners reported enjoying hands-on dissections more.

Skills development: 12 learners said hands-on dissections taught them more skills (e.g., dissection technique, teamwork, safe use of scalpels), while 3 pointed to ICT-related skills gained through simulations (e.g., interpreting animations, operating virtual tools).

Overall superiority: Most learners felt that both methods had strengths, with 11 suggesting a combination of both was best.

Qualitative analysis: the learners who preferred the simulated dissections mentioned ethical and sensory reasons, such as avoiding the smell of organs or concern about animal use. They also made note of the fact that "labels made structures easier to identify." In contrast, learners who favoured hands-on dissections emphasised the tactile and memorable nature of the activity, noting that "cutting the heart made it easier to remember where everything was" and that the experience was "more real." Interestingly, some learners suggested that hands-on dissections were especially useful for those considering health science careers, as they provided a chance to see what that kind of career would possibly entail.

4.2. Limitations of the study

When reflecting on the outcomes of this study a few limitations must be acknowledged, firstly this study was conducted at a single South African high school with a relatively small sample and as such cannot be used as a generalization to all learners or schools considering the fact that in South African schools we find great disparities in terms of socio-economic status and availability of resources.

The data collection relied on the pre-dissection and post-dissection test as well as the questionnaires and while this provided meaningful data, it may not have fully captured the learners understanding and long-term retention of the knowledge.

Each mode of dissection also carried its own limitations, what I mean by that is in terms of hands-on dissections the quality of the specimens may have influenced the learning outcomes and in terms of the simulated dissections the familiarity of the learners with the digital tools or the internet connection also may have influenced the learning outcomes.

On a much broader scale the study only covered the mammalian heart and cannot be used as a generalization to every topic and as such each topic should be addressed on a case-by-case basis.

4.3 Theoretical Analysis of Findings

4.3.1 Constructivist Learning Theory

Vygotsky (1978) argues that learners construct knowledge actively through direct engagement rather than passively absorbing information. This is particularly evident in the context of dissections, either through hands-on dissections or ICT simulated dissections. Both modes of dissection support this theory and it can be seen that overall, there was an improvement from the marks obtained in the pre-dissection test to the post-dissection test regardless of which mode of dissection was used.

In terms of hands-on dissections, when asked about the ventricular thickness in the pre-dissection test only 1 learner was able to answer the question correctly, however after conducting the hands-on dissection 9 learners were able to answer it correctly in the post-dissection test.

With regards to the simulated dissection, when asked to identify the septum the number of learners that answered correctly drastically improved from 3 learners in the pre-dissection test to 9 learners in the post-dissection test.

These results align with constructivism, which highlights that knowledge construction occurs differently depending on the form of interaction be it visual-digital (simulated dissection) or physical-tactile (hands-on dissection).

4.3.2 Experiential Learning Theory

In this study Kolb's (1984) experiential learning theory suggests that both methods enhanced learning in complementary ways.

Hands-on dissections provided learners with real life concrete engagement such as touching the ventricle walls to feel its thickness or seeing the fat that surrounds the heart, which were then integrated into reflective observation and conceptualisation. On the other hand, ICT simulations allows repeated trials and the visualization of processes, such as visualising blood flow direction, which was especially helpful when answering Question 10.

Both modes of dissection contributed to the understanding that learners gained in different ways tactile realism promoted sensory grounding, while simulations promoted iterative experimentation. This explains why many learners (11 out of 15 in the questionnaire) concluded that a blended approach would be most effective.

4.4 Synthesis of Findings

Overall, the analysis suggests that simulations are more effective for conceptual clarity and reducing misconceptions, while hands-on dissections are more effective for experiential realism and skill development. Both modes of dissection contribute to the overall understanding of the topic and as such a blended, hybrid approach when teaching the concept would be most beneficial.

4.5 Chapter Summary

The objective of this chapter is to analyse the data collected through the pre-dissection test, post-dissection test as well as questionnaire, to examine the challenges and advantages of hands-on and simulated dissections when teaching the mammalian heart to grade 10 learners.

The overall effectiveness of ICT simulated dissections is prominently visible in questions that require identification of structures for example when asked to label the septum only 3 learners were able to do so in the pre-dissection test, however, 9 out of 10 conducted the simulated dissection were able to correctly label the structure, while on the other hand only 3 of the 10 learners that conducted the hands-on dissection were able to answer the question correctly. A similar trend can be observed when learners were asked about the functions of the heart valves, learners that conducted the simulated dissection displayed substantial improvements. Initially of the 20 participants in the pre-dissection test, only 4 participants correctly answered the question and in the post-dissection test, of the 10 learners that took part in the simulated dissection was able to explain that the function of the valves to regulate blood flow, only one of the learners who conducted the hands-on dissection improved their answers in the post dissection test.

The impact that the hands-on dissection displayed can be seen in instances that dealt with physical aspects for example when asked to compare the thickness of the walls of the heart in the pre-dissection test only one learner could compare the thickness however 9 out of the 10 learners that conducted the hands-on dissection could now explain the differences in thickness. A similar trend can be observed when learners were asked to locate the fat deposits on the heart or when learners were asked to describe the texture of the heart.

However, it was also seen that there were instances where neither dissection had any measurable effect for example the learners were able to correctly answer how many chambers the heart has without having conducted either dissection this was also visible when learners were asked about the function of the pericardium or questions involving the circulation of blood within the heart. In these instances, the learners' answers were correct in the pre-dissection test and remained unchanged, suggesting that the theoretical lesson was sufficient for the learners' understanding of the concepts and that their knowledge was not significantly reinforced through either method of dissection.

From the results of this study, I was able to identify numerous challenges and opportunities surrounding different methods of dissections. Simulated dissections offer a learning experience that displays the structures clearly and where the labels are visible however they lack the physical and tactile experience that hands-on dissections offer. Hands-on dissections are often limited by specimen quality particularly as they need to be cut by the butcher making it difficult to identify structures and apply theoretical knowledge, the quality of the specimens is further unreliable as there are no two same hearts and therefore they differ in size, shape, etc. furthermore hands-on dissections bring about the question of ethical and safety considerations.

In terms of the learners' preferences and perceptions, their responses varied. Some learners preferred the clear visual representation and structural format that simulated dissection provides, while other learners favoured the tangible interactive nature afforded by a hands-on experience.

Holistically, both hands-on dissections and simulated dissections contributed to the learner's overall understanding in different ways, and both play a worthy role in the teaching and learning of the mammalian heart.

Chapter 5: Discussion of findings recommendations and Conclusion

5.0 Introduction

This chapter is an in-depth analysis that examines the results that were obtained from the pre-dissection and post-dissection tests, along with the questionnaire responses, in order to determine whether ICT-based simulations offer superior learning outcomes compared to traditional hands-on dissections when teaching the mammalian heart to Grade 10 learners. The chapter explores the effects of each method on learners' understanding, along with the associated challenges and opportunities, while also considering learner perspectives. A total of 20 learners were divided into two groups: one conducted an ICT-based simulated dissection (n = 10), while the other performed a hands-on dissection (n = 10). Both groups answered the pre-dissection after the theoretical lesson was taught they then conducted the dissection that they were allocated and thereafter wrote the post-dissection test, they later switched to the alternative method.

Additionally, 15 learners voluntarily completed a questionnaire to provide further insight into their experiences. The findings indicate that each dissection method presents distinct advantages and limitations, with the effectiveness of each approach depending on various factors, including learner preferences and the nature of the content being taught.

The overall findings suggest that both hands-on and simulated dissections contribute to the learning process in different ways. The effectiveness of each mode of dissection is influenced by multiple factors, which include learner perspectives and preferences, prior knowledge, teacher competence, etc. Through all of the findings, it was established that the most beneficial method would be to take a blended learning approach by using aspects of both modes of dissection. This was supported by Darras et al. (2019), who suggest that a hybrid approach that includes simulated and hands-on dissections will result in better anatomical understanding of the concept. Hou and Ouyang (2024) also advocated for a balanced approach between hands-on and simulated dissections.

5.1 Organization of Themes

The discussion is structured according to the research objectives , with the following themes:

Theme A: Impact of ICT Simulations
Theme B: Impact of Hands-on Dissections
Theme C: Areas Where Dissections Had No Significant Impact
Theme D: Challenges and Opportunities
Theme E: Learner Perceptions

5.1.1 Theme A: Impact of ICT Simulations

ICT simulations were particularly effective in facilitating the identification of anatomical structures such as the septum (Question 5) and heart valves (Question 6).

Learners using the simulation also demonstrated improved accuracy in labelling heart structures (Question 8), visualizing blood flow patterns (Question 10), and differentiating between valves (Question 17), their understanding was also demonstrate in the two new facts about the heart that they were asked to explain in the last question of the post-dissection test (Question 19).

The clarity of virtual models, with well-defined labels and animations, allowed learners to engage with the material more effectively than those working with physical specimens. This aligns with constructivist learning theory as it highlights the importance of active learning through interaction (Vygotsky, 1978). The elements that particularly align with Vygotsky's (1978) framework are the fact that ICT simulated dissections allow for repeatability until the learner is comfortable with the concept, but more prominently, they allow the learner to engage with the information independently. This is particularly visible when learners who took part in the hands-on dissection were unable to view or identify the labels that were required.

For instance, Question 5 dealt with identifying the structure that separates the left and right sides of the heart, and there was a notable increase in the number of learners who answered the question correctly in the post-dissection test, all of whom had conducted the simulated dissection.

The structures on the heart are not always easy to identify, and the learners who conducted the hands-on dissection were unable to distinguish between the right and left sides, and as a result, they were unable to identify the structure that separates the right side from the left side. Kaiser et al. (2023) maintained that the handling of the specimens directly impacts the clarity of anatomical structures. This is also evident in Wilson et al. (2017), who states that ICT simulated dissections overcome logistical challenges such as specimen quality and the quality of the preparation that are seen in hands-on dissection.

Contrary to this, the simulated dissection allowed learners to highlight each structure separately or to isolate each structure, and then the simulation provided the learners with the correct label for the structure, allowing them to label each part correctly. This also applies to Question 6, which asked learners to label the valves of the heart, and Question 8, which required learners to identify specific labels (Label 1: Pulmonary artery, Label 2: Superior Vena Cava, Label 3: Pulmonary Vein, Label 4: Right Atrium, Label 5: Left Ventricle, Label 6: Pericardium/Fat).

In the case of Question 10, learners were required to draw arrows on the test paper to indicate the flow of blood through the heart. This cannot be visualized through the hands-on dissection at all, but in the simulated dissection, animations are used to show the pumping mechanism of the heart and the pathway through which blood flows. This aligns with Cognitive Load Theory proposed by Sweller (1988). The theory states that visual aids, in this example ICT animations, can reduce cognitive load in order to make the concepts being taught easier to understand and remember. This is why the learners who conducted the hands-on dissection showed little or no improvement in the post-dissection test, while learners who conducted the simulated dissection were able to draw arrows indicating the flow of blood through the heart easily. Erolin et al. (2019) proposed the same stance, stating that virtual models, such as the animations used in the simulated dissection, improve learning outcomes.

Additionally, Snir et al. and Xiao and Adnan also supported the idea that ICT simulations allow learners to visualize abstract processes in order to better understand them. The element of repeatability is very prominent in simulated dissections, such that learners are able to do the same dissection a number of times until they are comfortable with it. This was also put forth by Owobabi and Bekele (2021).

Question 17 required learners to comment on the visual differences between the tricuspid and bicuspid valves. In learners who conducted the simulated dissection, three additional learners easily identified that in the tricuspid valve there are three cusps/flaps and the bicuspid has only two cusps/flaps. As for those who conducted the hands-on dissection, there were initially five learners who answered correctly in the pre-dissection test, and this number remained the same in the post-dissection test. This could be an indication that these five learners answered correctly from their theoretical knowledge or they were able to determine the difference using their knowledge of the prefixes to decipher the correct biological correlation. However, regardless of this, there was no improvement or decline due to the use of the hands-on dissection.

Question 19 was an open-ended question that asked learners to identify two things about the heart that they previously did not know.

The answers of the learners who conducted the simulated dissection overlapped and are summarized and discussed below:

- The heart has different types of valves.

- The opening and closing of the valves create the beating sound of the heart.
- Valves prevent backflow of blood.
- The way that blood flows through the heart.
- The heart is situated in the middle of the chest.
- Oxygenated and deoxygenated blood never mix.

The learners were able to observe that "the heart has different valves and how they open and close." We can infer that the learners were able to answer Question 17 correctly as they were able to see the primary visual differences between the bicuspid and tricuspid valves. When the learners commented on "how the valves open and close" and the identification of the lub-dub sound that the beating heart makes, this could only have been seen through the animation of the cardiac cycle that the simulation had offered. Learners also indicated a new understanding of how blood flows through the heart and the ability of the valves to prevent backflow of blood into the previous chambers; this was also only visible in the animation showing the cardiac cycle in the ICT simulation.

These are a few examples of the visual and auditory aspects that only an ICT simulation can offer. Another response that learners provided was that oxygenated and deoxygenated blood never mix. This indicated that the animation of the beating heart was very valuable to the learners' understanding of the heart. In the animation, it showed oxygenated blood in red and deoxygenated blood in blue, illustrating the manner in which it enters, exits, and is pumped through the heart. Without the ICT animation of the simulation, learners may not have been able to visualize the concept. In the ICT simulation, learners first see the heart in reference to the whole body.

It is often assumed that the heart is on the left side of your body, but in the simulation, it can be clearly seen that it is in the centre of your body, just slightly to the left. These findings align with previous research by Karbasi and Kalhori (2020), which emphasizes the benefits of using digital models in promoting interactive and structured learning experiences. Similarly, Owolabi and Bekele (2021) highlight that ICT-based dissections enhance conceptual understanding through repeated interactions with virtual anatomical structures. This allows learners to redo the dissection until they are comfortable with it and have developed an adequate understanding of the processes or structures. It should also be considered that the use of ICT in Life Sciences education, particularly with regards to dissections, has had a great impact on how learners deal with anatomy. Simulated dissections have gained popularity as a cost-effective alternative that overcomes accessibility and ethical issues (Zubek et al., 2024).

5.1.2 Theme B: Impact of Hands-on Dissections

Hands-on dissections have been found to provide the tactile feedback that learners gain understanding through. They allow learners to physically interact with specimens, creating a deeper understanding of key anatomical concepts, particularly those related to texture and structure.

The findings from this study align with existing research, highlighting the importance of physical interaction in fostering a deeper understanding of anatomy. It also aligns with the constructivist learning theory put forth by Vygotsky (1978), as hands-on dissections allow for inquiry-based learning as learners explore the organ in order to construct their own understanding of the anatomical structures. Hands-on dissections proved to be particularly beneficial in areas that required direct physical manipulation.

Learners who engaged in hands-on dissections demonstrated a stronger understanding of ventricle thickness (Questions 11 and 12), heart texture (Question 13), and the distribution of fat (Question 15). I will also comment on Question 19, which asked learners to comment on two aspects of the heart that they did not know before conducting the hands-on dissection.

The ability to physically touch and manipulate tissues provided learners with a deeper appreciation of structural differences, reinforcing the relationship between form and function. This aligns with the experiential learning theory of Kolb (1984). Kolb (1984) states that learning occurs through direct experiences, and hands-on dissections provide learners with real-world, hands-on engagement in order to aid in the learners' understanding and retention of the concept.

Hou and Ouyang (2024) put forth the stance that although simulated models have clear and visible representations of structures, they lack sensory interaction that enhances anatomical comprehension. My study supported this, and it was evident when learners using the ICT simulation were unable to identify differences in tissue texture and structural thickness. Physical feedback, such as feeling the firmness of the heart's ventricles or the softness of fatty deposits, plays a crucial role in understanding the relationship between structure and function. Cavicchi (2008) also supports this notion, as hands-on dissection allows for inquiry-based learning to develop muscle memory or hands-on skills used in dissections. This aligns with the findings in my study, as seen when learners who conducted the hands-on dissection were able to easily differentiate between heart chambers and structures.

The skills and muscle memory that come with a hands-on dissection have strong biological importance, particularly in medical sciences. The skills gained in hands-on dissections, such as dissection and specimen handling, require precision. If learners do not hone these skills, they may find it difficult to apply their knowledge in real-world laboratory or clinical settings.

In Question 11, learners were asked to describe the ventricular thickness and comment on its functionality. Learners who conducted the simulated dissection struggled with this, as only two learners improved their answer between the pre-dissection test and the post-dissection test. In contrast, in the hands-on dissection, a total of eight learners were able to comment on and describe the thickness of the ventricles after conducting the dissection. This finding aligns with Kaiser et al. (2023), who put forth the notion that by handling real specimens, learners are able to better understand spatial relationships and structural complexity. Question 12 required learners to draw lines to indicate the thickness of the ventricular walls. Three learners who conducted the hands-on dissection answered it correctly in the pre- and post-dissection tests; however, the other seven did not attempt it in either test. This could indicate confusion, as the thickness was not visible in the simulated dissection, even despite there being a three-dimensional animation.

On the other hand, the hands-on dissection displayed great improvement, from three correct answers in the pre-dissection test to nine correct answers in the post-dissection test. This can be supported by the work of Bogomolova et al. (2019), which stipulates that hands-on dissection allows for a greater understanding of spatial awareness, thus allowing learners to grasp the difference in the thickness of the tissue. When commenting on the texture of the heart in Question 13, those who conducted the simulated dissection showed no improvement, with two learners answering the question correctly in the pre-dissection test and the same two answering correctly in the post-dissection test.

The learners in the simulation group struggled with aspects related to texture and material properties, as digital models do not replicate tactile feedback. These findings corroborate research by Lombardi et al. (2021), which emphasizes the importance of hands-on experiences in fostering a deeper understanding of anatomy through sensory interaction. In contrast, the learners who conducted the hands-on dissection showed great improvement, from one learner initially answering this question correctly to nine learners answering it correctly in the post-dissection test. This can be attributed to the sensory stimulation that plays a crucial role in reinforcing theoretical knowledge, as suggested by Thisgaard and Makransky (2017), as well as Dauer and Dauer (2016) and Picatoste et al. (2017), who both highlight the importance of physical and tactile experiences that can be multisensory to enhance understanding.

When addressing Question 15, learners were asked to identify areas where fat is located on the heart. In the pre-dissection test, four of the learners who conducted the simulated dissection could describe its location, and the same four learners answered the question correctly in the post-dissection test. The description of the purpose of the fat was fairly well answered in the pre- and post-dissection tests; eight learners answered this sub-question correctly. This indicates that although the learners understood the function of the fat, they were unable to see the fat as it was not labelled on the diagram, possibly due to the fact that it was not explicitly labelled in the simulation. From the learners who conducted the hands-on dissection, in the pre-dissection test, three learners answered the location of the fat correctly, and eight answered the post-dissection test correctly. Eight learners answered the purpose of the fat correctly in the pre- and post-dissection tests, showing an improvement in identifying the location of the fat and its purpose. The fat was clearly visible on the specimen used in the hands-on dissection, and even though it was not labelled, learners quickly understood what it was. This aligns well with the findings of Kaiser et al. (2023) and Bogomolova et al. (2019), who stated that hands-on engagement allows for better visualization and appreciation of anatomical variations. They are also of the stance that physical interaction allows learners to observe structural differences that may be oversimplified or overlooked in simulations. When addressing Question 19, learners were asked to explain two concepts of the heart that they did not know before conducting the hands-on dissection.

Their answers are summarized below

- The human heart is smaller than a cow's heart.
- The walls of the aorta are much thicker than those of the pulmonary vein.
- There is fat surrounding the heart.
- There is a layer of pericardium.
- The human heart is the size of a fist.

For the hands-on dissection, we used a cow's heart, and as the learners began the dissection, they were very amused by how large the heart was and noted that "it would not fit in my chest." This would not have been visible in the simulated dissection, as the size of the organ can be manipulated and is not illustrated to scale. When the learners made this observation, I informed them that the average size of the human heart is about as large as your fist. This brought about the second fact of the heart that learners mentioned. This does not have a direct link to the use of hands-on dissections, but the conversation was only brought about through the observation that was made while conducting the hands-on dissection.

Some learners noted that in the hands-on dissection, they were able to distinguish between the thickness of the aorta and the pulmonary vein. They were able to feel the difference in thickness when touching and physically feeling the heart. This aligns with research conducted by Bogomolova et al. (2019), which indicated that hands-on dissections increase spatial awareness as well as understanding of structural differences. Kaiser et al. (2023) also support this notion when they mention the importance of physically handling specimens in order to deepen learners' appreciation of anatomy. These findings were also supported by Thisgaard and Makransky (2017), who argue that sensory feedback through direct manipulation aids in the learners' understanding of the concept at large.

The layers of pericardium and fat were clearly visible in the hands-on dissection, and learners were able to identify the difference between them on the physical heart as well as on the diagram given in the post-dissection test. They were also able to comment on the feel and texture of both components, in comparison with the simulated dissection where the pericardium was not visible and the fat was not clearly displayed.

5.1.3 Theme C: Areas Where Dissections Had No Significant Impact

For certain concepts, neither method produced a significant improvement in learner understanding. These included topics such as heart chambers, blood circulation pathways, the sound of a heartbeat, substances transported by blood, vessel functions, the dissection line, and the function of the pericardium (Questions 1, 2, 3, 4, 7, 9, 14, 16).

The minimal change in learner performance on these topics suggests that prior theoretical instruction had already provided sufficient foundational knowledge, and neither type of dissection substantially reinforced these concepts. This supports the Cognitive Load Theory (Sweller, 1988), which states that when prior knowledge on a concept is adequate and strong, any additional measures may not have a significant impact on the learning outcomes. This aligns with Xiao and Adnan (2022) research, which focuses on how ICT simulations are very beneficial when dealing with anatomically complex structures and concepts, especially ones that require dynamic representations. However, when dealing with simpler, well-established concepts that learners are already familiar with, such as the basic structure of the heart and its chambers, the simulated dissections may not show great improvements as the concept is fairly understood already. In a similar manner, Dauer and Dauer (2016) highlighted that hands-on dissections are most valuable for developing spatial awareness and practical skills, rather than reinforcing theoretical knowledge that has been taught in class.

The concepts that were being asked in Questions 1, 2, 3, 4, 7, 9, 14, and 16 did not require any practical skills, nor were they complex concepts that required an understanding of spatial awareness. As a result, the learners had already answered these questions well in the pre-dissection test; therefore, they required little or no improvement or changes in the post-dissection test. It is noted in the work of Hu et al. (2021) that the effectiveness of dissection methods varies depending on the nature of the concept being taught. My study's findings support this, as learners exhibited little improvement in areas where theoretical instruction had already been effective.

Snir et al. (1993) acknowledge that ICT simulations are widely valuable when visualizing abstract concepts or processes but hold little value when structures are well understood through theoretical lessons or textbooks. In this case, neither hands-on nor simulated dissections added considerable value, suggesting that although both methods of dissection hold value for the overall understanding of the topic, they must be used to reinforce the theoretical information that must also be taught.

5.1.4 Theme D: Challenges and Opportunities of simulated dissections and hands-on dissection in life sciences

Opportunities and challenges of ICT simulations in Life Sciences dissections

Cost-effectiveness of ICT simulations

ICT simulated dissections bear the notable advantage of being highly cost-effective, resulting in them being a popular solution for many educational institutes. The costs incurred by hands-on dissections are recurring, and in the South African economy, it can often be unrealistic to pay for the specimens, dissection tools, chemicals, and for the disposal of the specimens on a regular basis, all of which contribute to high ongoing costs (Jorquera and Vogel, 2021).

Simulated dissections involve a one-time investment to cover the costs of the software and hardware, and in some cases, there are online free alternatives that can be used with existing hardware. This can be used repeatedly without additional costs for physical materials (Achuthan et al., 2011). Although this setup cost may require significant funds, Zubek et al. (2024) have put forth the explanation that the long-term savings outweigh the ongoing expenses of dealing with live specimens (Zubek et al., 2024).

Many schools find using simulations for dissections a more sustainable approach that offers learners access to the same resources time and time again without ongoing financial implications (Hu et al., 2021). Additionally, simulated dissections can be referred back to; this can also be done remotely, and in practice, this means that it allows learners to revisit dissection exercises at no additional cost, reinforcing their understanding at their own pace (Owobabi and Bekele, 2021).

Logistical Considerations

A strong advantage that ICT simulations offer is that they aid in eliminating many logistical challenges that are often brought about by conducting hands-on dissections. ICT simulations are a practical way of overcoming these issues in such a way that learners are still exposed to a dissection without the added complications of managing live specimens (Zubek et al., 2024).

There is also the logistical challenge of the space required for laboratory setup; in cases where schools do not have a science lab, they may struggle to conduct dissections safely and effectively. However, should they opt to use a simulated dissection, it can be conducted in the classroom setting with tablets or computers (Zhang et al., 2020). The implication of this is that even in rural or underfunded schools, learners can explore anatomy through ICT simulations.

Another major logistical challenge that ICT simulations can overcome is that of the disposal and hygiene management of the specimens (Jorquera and Vogel, 2021). The curriculum also adds the pressure of time constraints, making it increasingly difficult to conduct hands-on dissections; therefore, simulations can be used as a time-efficient learning alternative (Owobabi and Bekele, 2021).

Overall, ICT simulations streamline the dissection process by addressing key logistical barriers such as specimen procurement, storage, classroom space, hygiene, waste disposal, and safety concerns. These advantages make virtual dissections an increasingly viable option for schools seeking efficient, accessible, and scalable alternatives to traditional hands-on dissections (Darras et al., 2019). This is a prime example of how Technology Integration and the TPACK Framework, as proposed by Mishra and Koehler (2006), can be used to address practical constraints in education by utilizing an ICT simulated dissection to overcome logistical and financial obstructions while still ensuring that meaningful teaching and learning takes place.

Skill Development

ICT-based simulations primarily support the development of digital literacy and technological proficiency, where learners gain valuable digital and analytical skills that are increasingly important in modern education.

As ICT has become more prevalent in scientific research and healthcare, developing proficiency in digital tools, data interpretation, and virtual modelling is essential for learners pursuing careers in STEM fields (Owobabi and Bekele, 2021). Although learners gain ICT-based skills, ICT simulations do not allow for the development of fine motor skills (Bogomolova et al., 2019).

The technology integration and the TPACK framework, as proposed by Mishra and Koehler (2006), highlight the integration of technology, pedagogical knowledge, and content knowledge to create interactive subject-specific content.

Ethical and Humanitarian Considerations

Simulations offer a viable alternative to traditional dissections, addressing ethical concerns related to animal use while eliminating issues associated with specimen procurement and disposal. Additionally, religious and cultural sensitivities surrounding animal dissections are alleviated through the use of virtual tools, aligning with concerns raised by King (2004).

A primary ethical concern in traditional dissections is cruelty to animals . Many learners and teachers are uncomfortable with the idea of animals being killed or used for educational purposes, particularly when viable alternatives exist (Zemanova, 2022). While some argue that dissection specimens are often byproducts of the meat industry, others contend that educational demand perpetuates unnecessary harm to animals. ICT simulations eliminate this issue entirely by allowing learners to explore anatomy without contributing to the use of animal specimens (Hu et al., 2021). In this study, some learners expressed that using a simulation was a more humane approach, as it did not require the use of a real cow's heart, reinforcing the argument that ICT simulations align better with ethical standards in modern education.
When discussing ethical considerations, religious and cultural beliefs surrounding the use of certain animals should also be addressed; Hinduism and Islam both restrict the

use and consumption of certain animals (Kline, 1995). ICT simulations remove these concerns by offering an inclusive and culturally acceptable manner of conducting dissections without violating their ethical or religious principles (Owobabi and Bekele, 2021).

Additionally, with ICT simulated dissections, concerns about food wastage arise, as some argue that the animal matter being used is wasteful and could be used as a food source, and since the specimens are considered medical waste, they must be discarded (Zemanova, 2022).
ICT simulations are a non-invasive, humane, and sustainable alternative that allows learners to engage in anatomical studies without the ethical implications of using live specimens (Kline, 1995).

Safety

ICT simulations mitigate the safety concerns that come with hands-on dissections. When conducting a simulated dissection, learners do not need to handle sharp instruments such as scalpels, which could possibly cause injury (Dauer and Dauer, 2016; George et al., 2022).

Handling live specimens also adds hygiene risks by exposing learners to bacteria and other microorganisms; ICT-based dissections remove this concern by creating a safer and cleaner learning environment while reducing institutional waste management responsibilities (George et al., 2022).

Lack of Tactile Engagement in ICT Simulations

ICT simulations lack the tactile engagement afforded by hands-on dissections. ICT simulations do not have the physical interaction that hands-on dissections provide; these interactions are important for developing a deeper understanding of anatomical structures (Zhang et al., 2020). ICT simulations do not allow learners to touch, manipulate, and physically dissect the specimens, preventing learners from experiencing the sensory experiences that contribute to spatial awareness, fine motor skills, etc. (Bogomolova et al., 2019).

Learners struggle to comprehend the texture, density, and thickness that come from physically manipulating the specimens. Noting that ICT simulations have limited tactile engagement, learners struggle to understand the relationship between structures and functions; without the sensory input of hands-on dissection, learners rely only on the visual aids provided, which may disadvantage kinaesthetic learners (Darras et al., 2019).

Technological Dependency and Accessibility Issues

ICT simulations are often dependent on electricity and connectivity, as well as technology and infrastructure; this can act as a barrier in cases where schools have limited resources, as the dissection will depend on reliable internet connectivity, functional hardware, and compatible software (Zhang et al., 2020). In areas where connectivity is scarce and inconsistent, as in many places in South Africa, this will impact the functioning and effectiveness of ICT simulated dissections.

Another major problem prominent in South Africa is that of load shedding, which is when scheduled power outages disrupt electricity supply, sometimes for several hours a day. If learners are using ICT simulations where they directly use computers, tablets, or smartboards, it will require electricity to function (Hu et al., 2021). However, even without the power outages, many schools in the South African context are underfunded or in rural areas that lack the access and infrastructure to support ICT simulated dissections (Owobabi and Bekele, 2021).

Oversimplification of Anatomical Structures

As seen in question 8 of the pre- and post-dissection tests, ICT simulations sometimes overlook or oversimplify some structures; in this case, when they overlooked the pericardium and fat around the heart. This causes learners to have a limited understanding of the structure, as they are using a visual representation that often lacks the natural complexity that a live specimen would have (Zhang et al., 2020). This can often lead to misconceptions about different structures, such as size, shape, and texture (Wilson et al., 2017). Simulated dissections use perfect models that lack natural variations, making them unrealistic (Dauer and Dauer, 2016). This means that the simulations do not have the realistic details that make them more relatable and practical.

Additionally, ICT simulations cannot recreate the texture and thickness of the tissues, while hands-on dissections allow learners to physically feel the differences between the thick, muscular walls of the ventricles and the softer, thinner walls of the atria; this structural adaptation links to its function, creating a deeper understanding of the relationship between structure and function (Kaiser et al., 2023).

Opportunities and Challenges of Hands-on Dissections in Life Sciences Education

Enhanced Spatial Awareness and Understanding of Anatomy

A great advantage of hands-on dissection is that they develop a sense of spatial awareness. This can be seen in question 19 when learners commented on the size of the human heart in comparison to the cow's heart. This is also visible in question 12, where learners were asked to comment on the differences in thickness of the walls of the heart. Learners who conducted the hands-on dissection answered these questions with ease, while those who conducted the simulated dissection struggled to comprehend the aspects being asked.

Hands-on dissection allows learners to physically conduct inquiry-based learning and exploration of the specimens, while ICT simulations utilize models of the specimens. The hands-on dissection allows learners to create a mental representation of the information, mapping out the different structures and the different tissues and components of the heart to create a complete model of the heart in their minds (Kaiser et al., 2023).

When learners dissect the physical specimens, they are able to observe the relative sizes and textures of different structures, reinforcing their understanding of spatial relationships (Dauer and Dauer, 2016). Another such example is when the learners observed the differences in ventricle thickness; this has also been observed in research suggesting that tactile and kinaesthetic experiences improve long-term retention of spatial concepts (Bogomolova et al., 2019).

In ICT simulations, learners are often restricted to fixed views and orientations; this limits the spatial awareness of learners. In contrast, hands-on dissections allow learners to manipulate the structures and view them from many different angles, where they can rotate and manually control structures, thus allowing learners to observe the full anatomical relationship of structures (Zhang et al., 2020).

Development of Fine Motor and Dissection Skills

Fine motor skills and dissection skills are almost only developed through the physical act of conducting hands-on dissection; these skills are valuable in biological and medical careers. The hands-on dissection requires precision, coordination, and high levels of care when handling specimens (Bogomolova et al., 2019); these aspects are not emphasized, and these skills are not honed when conducting simulated dissections.

Hands-on dissections have an added risk, as learners are working with instruments such as scalpels, forceps, and probes (Wilson et al., 2017); however, the structured use of these instruments promotes a high level of care when conducting the dissection, unlike simulations which have programmed interactions and instructions. The hands-on dissection, therefore, reinforces responsibility and safety within the laboratory.

Improved Retention and Recall of Information

A major advantage that hands-on dissections have is that they offer an active and engaging experience where learners are required to physically interact with the specimens. There is no opportunity for passive observation, as sometimes allowed by simulated and pre-programmed dissections (Dauer and Dauer, 2016).

The direct physical nature of hands-on dissections promotes inquiry-based learning and problem-solving skills; these, in turn, lead to deeper engagement and retention of knowledge. The hands-on experience has been found to improve learner motivation, curiosity, enjoyment, and engagement (Bogomolova et al., 2019). Hands-on dissections promote curiosity and problem-solving skills without immediate feedback providing the labels of structures like in a simulated dissection (Owobabi and Bekele, 2021).

When learners dissect the heart, they are able to observe the interconnected structures and, in turn, how they function together to perform the function of the heart.

This aligns with work by Kaiser et al., which explains that learning by doing is more effective than passive observation in scientific education (Kaiser et al., 2023).

Hands-on dissections force learners to use multiple senses, i.e., touch, sight, and even smell; this creates a stronger memory of the concept, which learners can recall more easily (Picatoste et al., 2017). This is due to the fact that the learners now experience the information through multiple cognitive pathways (Bogomolova et al., 2019).

The multisensory nature of hands-on dissections improves memory retention; this is because learners are more likely to remember concepts they have interacted with in a physical manner rather than by observing them passively on a screen (Dauer and Dauer, 2016). Learning is an active process and not merely receiving information (Kaiser et al., 2023). Learners' understanding of a concept is reinforced through direct engagement (Owobabi and Bekele, 2021). ICT simulations cannot recreate the physical act of dissecting the heart, limiting learner engagement (Zhang et al., 2020). It is evident in this study that through the physical handling of the specimens, learners were able to remember structural differences, such as ventricle thickness and the placement of valves, more easily than when using digital simulations.

Hands-on dissections improve learners' ability to recall information, as the conclusions they have drawn arise from problem-solving skills; what I mean by this is that in the case of ICT simulated dissections, learners have to simply click on a structure to see its label and function (Xiao and Adnan, 2022), but when using hands-on dissections, learners have to actively search for and recognize structures on their own, which promotes critical thinking skills to locate and identify structures without digital guidance (Dauer and Dauer, 2016).

The tactile nature of hands-on dissections creates a kinaesthetic learning experience, which consolidates the relationship between structure and function (Dauer and Dauer, 2016); therefore, hands-on dissections are effective in improving retention and recall of anatomical information, as they engage learners in active, multisensory learning that strengthens memory and understanding (Dauer and Dauer, 2016; Bogomolova et al., 2019).

Challenges of Hands-on Dissections

Ethical, Humanitarian and logistical constraints

There are two major challenge when dealing with hands-on dissections the first being ethical and humanitarian concerns related to animal welfare, religious beliefs, food wastage, and environmental impact (Zemanova, 2022).

As animal organs are also a food source, the use of them as specimens when conducting dissections raises concerns, as food security is a global issue (Zemanova, 2022). Furthermore, because these specimens are classified as medical waste products, they must be disposed of accordingly, and therefore the specimens cannot be repurposed for consumption or other uses (Jorquera and Vogel, 2021).

Animal welfare activists have highlighted the concerns when using hands-on dissections; this was also brought up by learners in my study, where learners indicated that although used for educational value, the use of live specimens causes harm to the animal population (Zemanova, 2022). Another concern that learners identified is that of religious limitations; in Islam and Hinduism, the use of certain animal products is prohibited; therefore, conducting dissections using these animal products goes against their religious beliefs (Kline, 1995). In my study, learners also indicated being uncomfortable due to their religious restrictions or conflicts (Owobabi and Bekele, 2021). In cases such as this, ICT simulations offer an inclusive alternative, regardless of their religious background or values.

Another humanitarian concern deals with the psychological well-being of learners when conducting hands-on dissections, as some learners experience distress, nausea, or emotional discomfort when handling real animal organs, which can hinder their engagement with the lesson. From the perceptions of learners in my study, a number of them indicated that they preferred the simulated dissection, as this mode of dissection did not involve blood, tissue, or smells that are generally associated with hands-on dissections (Thisgaard and Makransky, 2017).

The second major issue when dealing with hands-on dissections is that of the logistical issues that surround this mode of dissection, with regards to the logistical issues the first concern is that of which is the actual procurement of the specimens; this is a costly undertaking, and schools require a number of hearts to ensure that all the learners are involved in the dissection (Wilson et al., 2017). Additionally, when the hearts are procured, there is no guarantee that they will be cut correctly or of a high standard; this will be explained further in the next subtopic. It is almost impossible to ensure that any two hearts are exactly the same, highlighting the question of specimen quality, which I will also address later in the chapter.

The second logistical issue is the storage of these specimens; not all schools may have the resources to store the hearts due to limited lab facilities (Hu et al., 2021).

On the topic of laboratory facilities, that brings me to the third logistical issue, which is that the lab setup occupies a great deal of space, as a well-equipped lab would require sinks, safety equipment, and proper ventilation to handle specimens (Wilson et al., 2017).

Safety Risks and Hazardous Materials

Hands-on dissections pose the significant challenge of hazardous exposure and associated safety risks. Hands-on dissections provide important experiences, but they could also pose potential dangers.

When conducting dissections, learners are required to use sharp and dangerous instruments such as scalpels and probes; this can be advantageous in teaching responsibility and safety, but children will be children, which brings about a great risk and responsibility on the side of the teacher, requiring strict supervision to prevent injury (Dauer and Dauer, 2016).

Hands-on dissections also expose learners to microorganisms involved with the biological specimens; the risk of this increases greatly, particularly if the specimens are not stored, handled, or disposed of correctly (Wilson et al., 2017), which may carry bacteria, pathogens, or other contaminants, increasing the risk of infection or allergic reactions among learners (Jorquera and Vogel, 2021).

There is one additional risk: learners may experience distress and psychological discomfort; the anxiety, nausea, or emotional distress that comes from handling animal organs, particularly if they have ethical concerns or sensitivities to blood and tissue (Arun, 2017). Some of the learners in my study indicated that they preferred ICT-based dissections because they avoided the psychological discomfort. Research suggests that offering alternative learning methods, such as virtual dissections, helps accommodate learners who may be uncomfortable with traditional dissections (Thisgaard and Makransky, 2017).

Inconsistency in Specimen Quality

When conducting hands-on dissections, the quality of the specimens has a direct impact on how effective the learning experience is. ICT simulations can create a standard model; however, the live specimens differ in condition and structural integrity (Wilson et al., 2017). The manner in which the hearts are cut by the butcher to prevent them from being sold for human consumption on the black market also impacts the effectiveness of the learning that takes place (Jorquera and Vogel, 2021). All of these inconsistencies result in difficulty when identifying biological structures, which in turn results in reduced learning outcomes (Darras et al., 2019).

Due to legal implications, butchers and abattoirs are required to cut through the cow's heart before it is sold, which means that the hearts that learners work on in the hands-on dissection are already partially dissected or cut; the way that they are cut is often not aligned with biological dissections and cuts through organs that learners are required to identify.

This was observed in my study, as learners were unable to identify some structures due to the manner in which they were cut open (Jorquera and Vogel, 2021). However, regardless of whether the heart specimens are cut by the butcher or not, the hands-on dissections are more difficult to see specific structures and to be able to distinguish between them; therefore, learners are unable to learn about the heart's internal anatomy as intended (Hu et al., 2021). Limited resources at schools result in the use of poor quality specimens, if schools had a larger budget for dissections they would be able to source higher grade organs that could be used for dissections that were not cut open or incorrectly by the butcher.

Due to the fact that hands-on dissections rely on live specimens, no two specimens can be anatomically identical; they differ in size, shape, and structure (Dauer and Dauer, 2016). This can make it difficult to compare the specimens to other specimens and the theoretical information in the textbook or models (Bogomolova et al., 2019).

Time Constraints in Curriculum

An ongoing concern for all teachers is the time constraints stipulated by the curriculum; this makes taking time out for hands-on dissections increasingly difficult, as time is taken to set up, conduct the dissection, dispose of the specimens, and clean up. This requires significant instructional time, as teachers must source the specimens, set up the instruments and resources, explain the process to learners, explain the safety regulations to learners, etc. (Wilson et al., 2017). This makes it difficult to balance the objectives of the lesson with the time allocated for it, which may create an incomplete or rushed experience (Darras et al., 2019). This also takes time away from the actual theoretical lessons that take place in the classroom (Hu et al., 2021).

In the case of ICT simulated dissections, learners are able to immediately engage with virtual models without the need for setup or lengthy explanations (Darras et al., 2019). ICT simulations can be paused if need be and can be resumed in the next lesson; however, hands-on dissections have to be completed in the time allocated to ensure that the specimens do not deteriorate and are disposed of correctly (Wilson et al., 2017).

The syllabi are very content-heavy and do not allocate enough time for dissections to be conducted hands-on, despite their educational importance; therefore, many teachers prioritize theoretical instruction over practical activities (Darras et al., 2019). Even when dissections are conducted, these time constraints force teachers to go through the process quickly, which can impact learner understanding and engagement (Hu et al., 2021).

5.1.5 Theme E: Learner Perceptions

Enjoyment and Preference

After experiencing both methods, most learners expressed a preference for hands-on dissections, citing engagement, realism, and tactile learning as key factors. However, some learners favoured ICT-based simulations due to ethical concerns, sensitivity to smells, or discomfort with handling real specimens.

Comparative Effectiveness

Statistical analysis revealed a significant preference for hands-on dissections over simulations ($p < 0.001$, $F(1, 92) = 26.24$). However, ICT-simulated dissections were perceived as more user-friendly ($p = 0.014$, $F(1, 92) = 7$). While hands-on dissections were favoured for engagement and retention, learners acknowledged that simulations facilitated structural identification and comprehension. These findings align with the perspectives highlighted by Jones et al. (2020), who argue that hands-on dissections feel more

Skill Development

Both hands-on and simulated dissections promote skills development. In the case of simulated dissections, the type of skills that are promoted is highly based on digital literacy (Darras et al., 2019), while hands-on dissections foster practical dissection and laboratory skills, which are often very valuable in scientific fields (Zhang et al., 2022).

Ethical Considerations

The ethical implications of hands-on dissections can be addressed by utilizing ICT simulated dissections as an alternative for learners uncomfortable with animal dissections. This mitigates religious concerns as well as those associated with food wastage and animal welfare (Zemanova, 2022).

Engagement and Memory Retention

In this study, it was found that learners generally preferred hands-on dissections, as they found it to be more interactive and immersive. They noted that physically touching the heart made it easier to remember; this could possibly be because it employs inquiry-based learning. They were therefore able to remember the structures more effectively, supporting research that suggests experiential learning enhances memory retention (Bogomolova et al., 2019).

On the other hand, ICT simulations often cater very well to visual learners; therefore, learners who primarily require visual stimulation may benefit from these simulations more.

<u>Statistical Comparison of Marks Obtained</u>

From the marks obtained by learners in the pre-dissection and post-dissection tests, there was an overall improvement in the learners' understanding of the heart, regardless of whether they conducted the hands-on dissection or the simulated dissection. This was evident from the increase in marks obtained in the post-dissection test compared to the pre-dissection test.

The mean for the overall improvement across all learners was 14.15 out of 30 (47.17%) in the pre-dissection test to 17.85 out of 30 (59.5%) in the post-dissection test, and the overall percentage increase was 26.14%, suggesting that any dissection activities (hands-on or simulated) contribute positively to conceptual understanding. This aligns with existing literature, which emphasizes the benefits of active learning strategies in biological education (Cleveland et al., 2017).

<u>Comparison Between Hands-on and ICT-Simulated Dissections</u>

I then looked at each set of data separately. The data showed the differences in learner performance between the hands-on dissection and the simulated dissection. The learners who conducted the hands-on dissection obtained a mean score of 16.2 (54%) in the pre-test and 20 (66.67%) in the post-test, resulting in a percentage increase of 23.46%. On the other hand, learners who engaged in the ICT-simulated dissection started with a mean of 11.9 (39.67%) and improved to 15.7 (52.33%), reflecting a percentage increase of 31.91%.

This indicates that both modes of dissection improve understanding; with regards to ICT-simulated dissections, the percentage increase was 31.91%, which was higher than that of hands-on dissections at 23.46%. This highlights the effectiveness of ICT simulated dissections in the identification of structures, especially for learners who have ethical concerns or logistical challenges associated with hands-on dissections (Darras et al., 2019; Owobabi and Bekele, 2021).

Overall, the data indicated that both hands-on and ICT-simulated dissections enhance learners' understanding of the mammalian heart. This is a clear indication of the alignment of blended learning frameworks (Garrison and Kanuka, 2004), as it highlights the complementary nature of ICT simulations to hands-on dissections in order to utilize the elements of each that are most beneficial to learning.

5.2 Recommendations

This study found that both ICT simulations and hands-on dissections contribute uniquely to anatomy education. Each mode of dissection has its own opportunities and limitations.

ICT simulations offer visual clarity, ethical viability, and accessibility, while hands-on dissections provide tactile engagement, practical experience, and deeper anatomical appreciation.

In order to ensure maximum learning outcomes, it is my recommendation that a hybrid model be used. The hybrid model will integrate hands-on aspects as well as simulated aspects. This approach ensures that learners benefit from the advantages of both digital and physical dissections, thereby catering to diverse learning preferences and enhancing overall comprehension. A hybrid model will align with the works of Vygotsky (1978) as well as Kolb (1984); in terms of the constructivist learning theory, both hands-on and ICT simulated dissections are important for learning to take place. ICT simulated dissections allow for repeatability and provide a visual and interactive platform within which learners are able to construct their own understanding of the concept.

On the other hand, hands-on dissections allow for the direct manipulation and exploration of specimens, through which learners are able to construct their own understanding of the concept (Vygotsky, 1978). By integrating both models to create a hybrid model, we are able to utilize different elements of each mode in order for learners to create the most reliable understanding of the concept. With regards to the experiential learning theory, a blended approach using both hands-on and ICT simulated dissections will maximize learning outcomes, skills development, and learner engagement by bringing together theoretical content with different methods of dissection (Kolb, 1984).

An ICT simulation could be used as an introductory tool to teach the structure and components involved, which could then be followed by the theoretical lesson and finally the hands-on dissection. As a form of reinforcement, the ICT simulation could be referred back to after the hands-on dissection. This aligns with the hybrid learning and blended approach (Garrison and Kanuka, 2004) by suggesting the integration of traditional methods and digital tools in order to leverage the most beneficial aspects of each mode to bring about the best learning outcomes.

5.3 Recommendation for the Implementation of a Hybrid Dissection Model in Life Sciences Education

My recommendation based on the findings of my study is that teachers adopt a hybrid dissection model. A hybrid model will use aspects of both hands-on dissections and ICT-simulated dissections. This will ensure that learners are provided with the most thorough understanding of the heart’s structures and functions. This model is inclusive of different learning styles and is able to address some of the ethical, logistical, and resource-related challenges generally related to dissection.

In doing this, we are able to make the most of both dissection methods by leveraging the advantages of each and overcoming some of the limitations of each. This model, in turn, improves engagement, understanding, retention, and skill development of learners.

Enhancing Conceptual Understanding and Engagement

By utilizing a hybrid dissection model, learners are able to engage with both digital and physical aspects. This will improve learners' understanding of the concept. ICT-simulated dissections provide visual elements for biological structures and processes; it also provides a step-by-step labelling approach before learners conduct the hands-on dissection. This exposure to the structures and functions reduces cognitive overload and assists in laying the foundation of knowledge at their own pace, allowing them to refer back to the knowledge as often as needed. While the 3-dimensional simulated model reinforces concepts, particularly the labelling aspect of the topic, it lacks the sensory element of working with real tissue. However, this will be provided to the learners through the hands-on dissection.

When learners then conduct the hands-on dissections, they are provided with an interactive experience that has a tangible element, through which learners are able to observe the texture, consistency, and spatial relationships of structures. Hands-on dissections consolidate knowledge through multisensory stimuli, which helps in retention and understanding. Each method of dissection impacts learner engagement in a different way, but by utilizing both methods, there will be a significant increase in participation overall.

All in all, a hybrid model would ensure a well-balanced learning experience, maximizing learner outcomes, by integrating both modes of dissection.

Addressing Ethical, Logistical, and Resource Challenges

Hands-on dissections raise concerns about the ethical treatment of live specimens. Learners, teachers, and educational institutions have questioned the treatment of animals used for dissections. The use of a hybrid model will reduce the number of live specimens needed for the hands-on dissection; this is done by using ICT-simulated dissection to supplement the lessons, addressing ethical concerns.

In terms of logistical challenges and lack of resources, the availability of specimens and expense around resources limit the ability of schools to conduct hands-on dissections. ICT simulations provide a cost-effective alternative through which learners are able to explore the structures in the dissection. In the case of under-resourced schools that often struggle to obtain the necessary tools required for hands-on dissections (such as scalpels, gloves, and laboratory space), when using ICT simulations, learners are provided with a high standard of education even when hands-on dissections are not possible.

Using a hybrid model also mitigates some of the psychological trauma that learners may experience. ICT simulations also provide an alternative to hands-on dissections that overcomes religious objections against dissecting live specimens. In the hybrid model, learners are able to first engage with the ICT simulation, which allows them to mentally prepare themselves, facilitating an easier transition to the hands-on dissections.

Improving Learner Retention and Skill Development

In order for the lesson outcomes to be considered successful, learners must be able to retain the knowledge of the anatomical structures of the heart; this is even more valuable for learners who wish to pursue health sciences careers. This is achieved through active engagement, which will improve long-term memory recollection.

By using a hybrid model, learners can utilize the repeatability of simulated dissections, which improves retention of knowledge through multiple sensory and cognitive pathways; ICT simulations also enhance digital skills. Hands-on dissections offer tactile experiences while improving laboratory and fine motor skills, which prepare learners for real-world applications. The skills associated with hands-on dissections come from manipulating live specimens; this requires precision, dexterity, and careful observation. Overall, a hybrid model provides learners with cognitive understanding and technical proficiency, equipping them for practical applications.

Accommodating Diverse Learning Needs

Every learner has their own individual learning style; therefore, a hybrid model caters to diverse cognitive preferences. It employs visual and kinaesthetic aspects, accommodating different learning styles, which in turn improves learning outcomes through inclusive teaching practices.

Visual learners

When considering visual aspects, ICT simulations provide high-quality images of structures, which often include interactive labels and animations. This makes it easier for learners to identify and understand the different components of the heart. This type of dissection also allows learners to zoom in on structures and rotate the organ in order to improve their understanding of the topic at hand.

Kinaesthetic learners

In the case of kinaesthetic learners, hands-on dissections tend to be beneficial as they offer the opportunity for learners to directly manipulate and interact with specimens. The engagement with tissues promotes a deeper understanding of the spatial features of anatomical structures. The tactile element of hands-on dissections improves muscle memory and fine motor skills. Regarding simulations, the interactive and gaming elements provide stimulation for learners. A hybrid model allows students to first familiarize themselves with anatomical structures through ICT before progressing to hands-on dissections. The hybrid model provides inclusivity and accessibility for all students.

Practical Implementation in the Classroom

In order for the implementation of a hybrid model to be effective, teachers are required to consider multiple elements of both dissections. This has been taken into consideration, and below is a possible method to implement the hybrid model into the classroom.

Step 1: Introduction - ICT-Simulated Dissection

The ICT simulation can be used to introduce the topic. This may be done by the teacher displaying the simulation on the smart board, where learners can work together as a class. They are given the opportunity to explore the 3-dimensional model of the heart, where they are able to view and identify the structures of the heart in an interactive manner. Learners could also engage in guided quizzes that ICT simulations offer as an introductory activity.

Step 2: Theoretical Lesson - Reinforcement

In this step, learners would be taught the topic of the mammalian heart (theoretical lesson). This is when the finer details about the structures and functions of the heart would be taught to the learners. At this point, learners could also be guided in a class discussion about the ethical considerations of dissection in order to instil values and appreciation for biological structures.

Step 3: Hands-On Dissection - Phase

At this stage, learners would move to the laboratory set up to conduct the hands-on dissection of a mammalian heart, the hands-on dissection could be conducted on cow hearts; this step allows learners to apply theoretical knowledge that they now have and apply it to the real world. In this step, learners are able to apply scientific inquiry in order to improve their understanding of the topic.

Step 4: ICT Simulation - Review and Consolidation

At this step, the teacher could redirect learners to the simulation again in order to revisit structures and compare digital models with real specimens. They could administer an informal assessment of the learners' understanding could be done through digital quizzes.

In order for the learning outcomes to be positive, teachers require training on integrating ICT simulations with hands-on activities. It is also vital that the schools are equipped with the resources required for each mode of dissection in order to facilitate the lesson.

5.4 Alignment of Theoretical Frameworks

Of the theoretical frameworks outlined in my study, the most prominent were:

- Hybrid Learning and Blended Approaches
- Constructivist Learning Theory

5.4.1 Hybrid Learning and Blended Approaches

The aim of my study was to compare hands-on dissections and ICT simulated dissections; however, ultimately the recommendation that I made was the implementation of a hybrid model which integrates the most beneficial aspects of each mode of dissection in order to bring about the best learning outcomes. This can be done to ensure that learners are provided with the tactile experience of hands-on dissections as well as the digital clarity and visualization of hands-on dissections.

While both hands-on dissections and ICT simulated dissections have their opportunities and limitations, a hybrid model is able to leverage the most useful elements of digital tools and traditional methods in order to bring about meaningful learning.

5.4.2 Constructivist Learning Theory

Vygotsky's Constructivist Learning Theory (1978) emphasizes the importance of active learning engagement. Learners need interaction and exploration in order to construct meaning and knowledge; this can be achieved in the real world or in virtual environments. This exploration and interaction also highlight the importance of inquiry-based learning, problem-solving, and critical thinking skills.

Future research could explore the long-term retention of knowledge gained from each method and investigate how blended approaches can be optimized for Life Sciences education.

5.5. Conclusion

This aim of this study was to compare the effectiveness of traditional hands-on dissections and ICT simulated dissections when teaching the mammalian heart to grade 10 Life Sciences learners, by comparing the extent to which each mode of dissection influenced the understanding of the learners while examining the challenges and opportunities of each mode as well as the perceptions of learners.

The results indicated that both modes of dissection had strong educational benefits as well as limitations. Hands-on dissections provided a sensory rich experience which also developed learners' laboratory skills and spatial awareness. On the other hand, simulated dissections provided a ethical alterative that overcomes religious and cultural barriers while allowing the learners to repeat the dissection in a controlled digital environment.

However, despite the advantages of both modes of dissection neither method was outrightly superior to the other and as such the evidence suggests that the most beneficial approach is that of a hybrid model, this approach offers the most pedagogically sound pathway as it incorporates both hands-on and ICT simulated dissections. It uses the advantages of each mode of dissection, while overcoming the limitations of each.

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Appendices

Appendix 1: Pre-dissection test

1. How many chambers does the heart have?
2. The movement of blood through the body is known as?
3. The beating sound your heart makes comes from:

A) Blood going in the wrong direction

B) Valves closing

C) The heart skipping beats

D) Your ears playing tricks on you

4. With circulation, the heart provides your body with:

A) Oxygen

B) Nutrients

C) A way to get rid of waste

D) All of the above

5. What wall separates the left side and right side of the heart?

A) Ventricle

B) Atrium

C) Septum

D) The great wall

6. What parts act like doors that control blood flow in the heart?

A) Valves

B) Heart dams

C) Kidneys

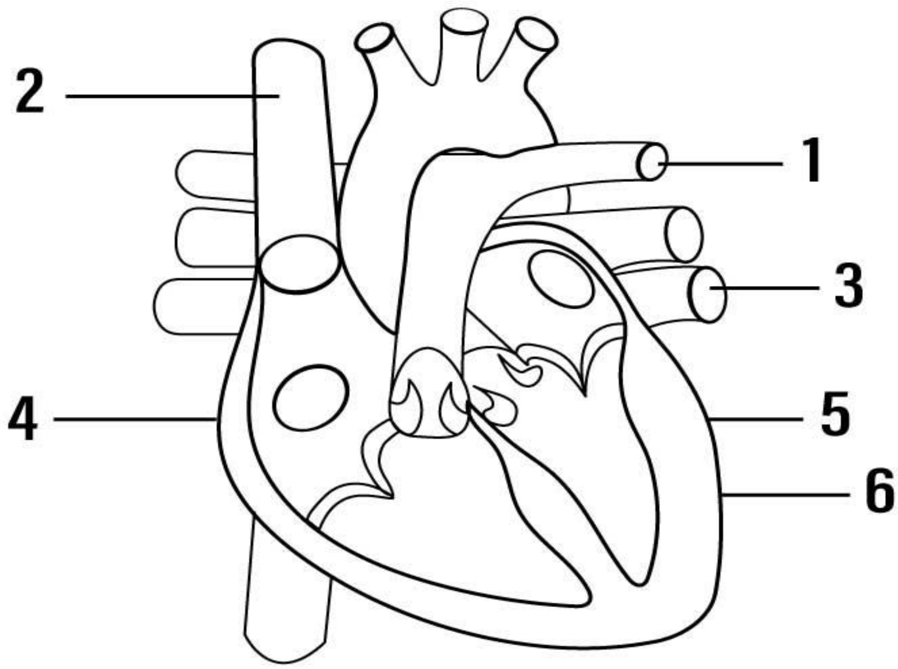
D) Chambers

7. What are tubes that carry blood back to the heart

8. Label the diagram below

9. On the diagram below draw a dotted line to show where you would cut in order to dissect the heart

10. On the diagram below draw two arrows to show the flow of blood through the heart



11. What is the name of the structures that allow blood not to flow backwards in the heart?

12. How does the structure above perform its function?

13. Describe the difference in thickness of the different chambers

14. Why do you think there is a difference in thickness?

15. What function does this difference in thickness perform?

16. Describe the differences in the texture of the tissue on the inside and outside of the heart.

17. What is the function of the heart cords and how do the cords perform this function?

18. Which part of the body does the superior Vena cava pump blood to?

19. Where is the superior Vena cava positioned?

Appendix 2: Post-dissection test

1. How many chambers does the heart have?
2. The movement of blood through the body is known as?
3. The beating sound your heart makes comes from:

A) Blood going in the wrong direction

B) Valves closing

C) The heart skipping beats

D) Your ears playing tricks on you

4. With circulation, the heart provides your body with:

A) Oxygen

B) Nutrients

C) A way to get rid of waste

D) All of the above

5. What wall separates the left side and right side of the heart?

A) Ventricle

B) Atrium

C) Septum

D) The great wall

6. What parts act like doors that control blood flow in the heart?

A) Valves

B) Heart dams

C) Kidneys

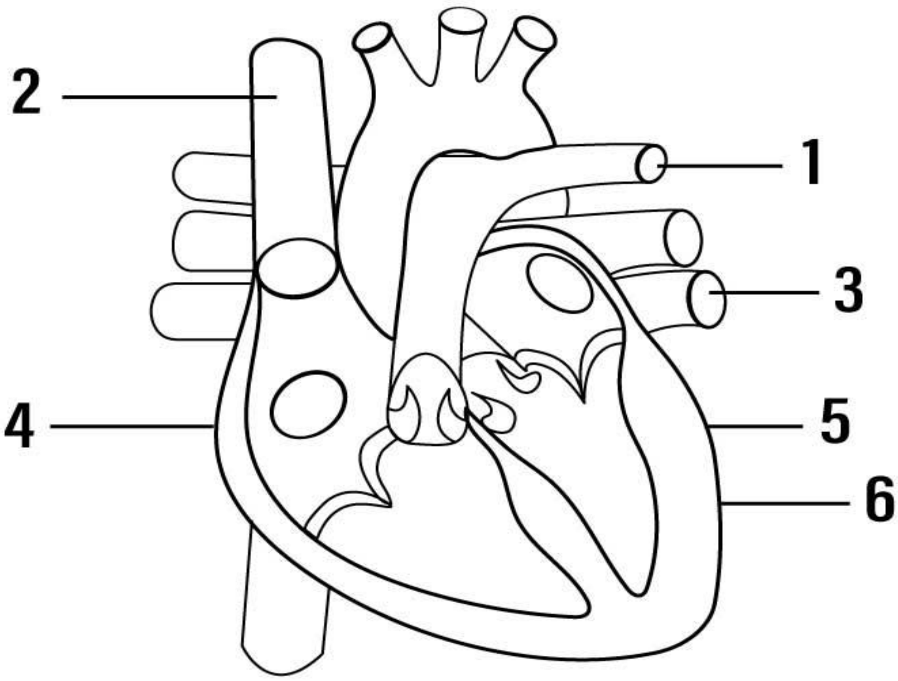
D) Chambers

7. What are tubes that carry blood back to the heart

8. Label the diagram below

9. On the diagram below draw a dotted line to show where you would cut in order to dissect the heart

10. On the diagram below draw two arrows to show the flow of blood through the heart



11. What is the name of the structures that allow blood not to flow backwards in the heart?

12. How does the structure above perform its function?

13. Describe the difference in thickness of the different chambers

14. Why do you think there is a difference in thickness?

15. What function does this difference in thickness perform?

16. Describe the differences in the texture of the tissue on the inside and outside of the heart.

17. What is the function of the heart cords and how do the cords perform this function?

18.1 Which part of the body does the superior Vena cava pump blood to?

18.2 Where is the superior Vena cava positioned?

19. Describe two things about the heart that you did not know before conducting the dissection

Appendix 3: Test answers

1. How many chambers does the heart have?

4

2. The movement of blood through the body is known as?

Circulation

3. The beating sound your heart makes comes from:

A) Blood going in the wrong direction

B) Valves closing

C) The heart skipping beats

D) Your ears playing tricks on you

B

4. With circulation, the heart provides your body with:

A) Oxygen

B) Nutrients

C) A way to get rid of waste

D) All of the above

D

5. What wall separates the left side and right side of the heart?

A) Ventricle

B) Atrium

C) Septum

D) The great wall

C

6. What parts act like doors that control blood flow in the heart?

A) Valves

B) Heart dams

C) Kidneys

D) Chambers

A

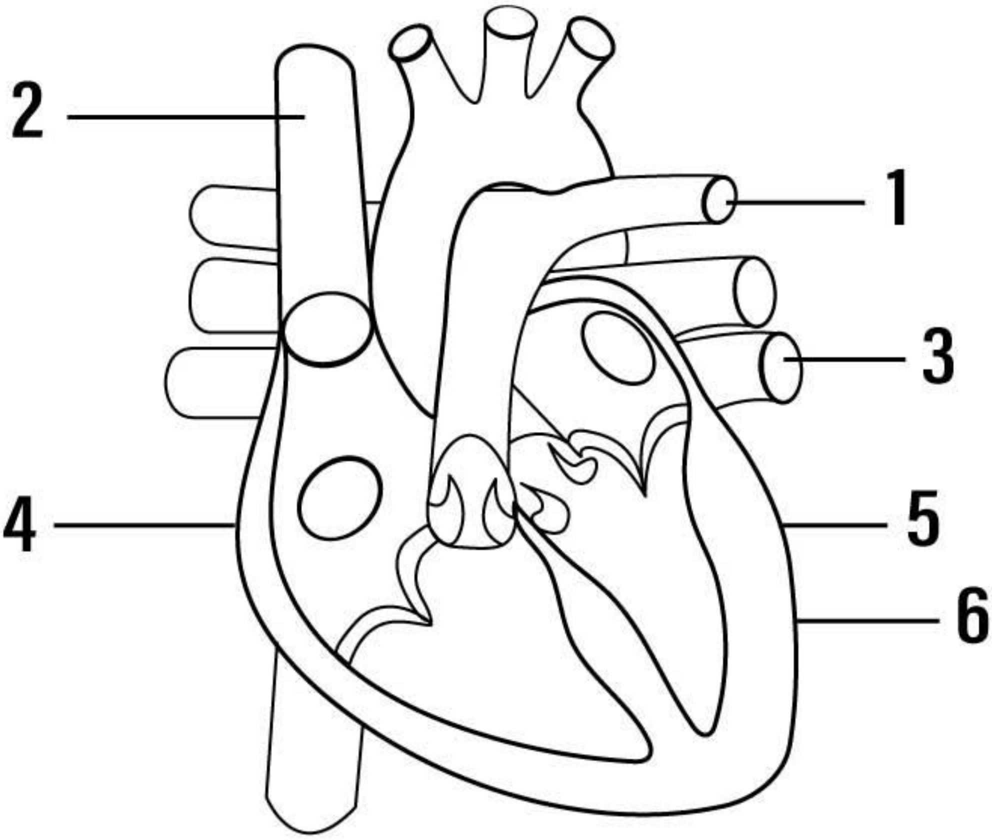
6. What are tubes that carry blood back to the heart

Veins

7. Label the diagram below

8. On the diagram below draw a dotted line to show where you would cut in order to dissect the heart

9. On the diagram below draw two arrows to show the flow of blood through the heart



10. What is the name of the structures that allow blood not to flow backwards in the heart?

aortic valve, mitral valve, pulmonary valve and tricuspid valve

11. How does the structure above perform its function?

They open and close to let blood flow from one area of your heart to another. They help ensure that blood moves at the right time and in the correct direction. As the valves open and close, they create two sounds, which are your heartbeat.

12. Describe the difference in thickness of the different chambers
13. Why do you think there is a difference in thickness?
14. What function does this difference in thickness perform?

The following answers apply for question 13,14 and 15

The left ventricle has the thickest wall out of all the chambers.

The left ventricle is responsible for pumping the blood towards the tissues of the heart.

This is why more muscles contracting inside the left ventricle helps produce a higher force to move the blood towards the system.

The right ventricle is responsible for pumping the blood to the lungs.

It has thicker walls compared to the two atrium, but thinner than the left ventricle.

Right auricle or the right atrium contains less cardiac muscles and hence thinner walls.

Left auricle or the left atrium contains less cardiac muscles and hence thinner walls.

Left ventricle of heart has the thickest wall.

15. Describe the differences in the texture of the tissue on the inside and outside of the heart.

Epicardium Visceral layer of serous pericardium

Comprised of mesothelial cells and fat and connective tissues

Myocardium Muscle layer

Comprised of cardiomyocytes

Endocardium Lines inner surface of heart chambers and valves

Comprised of a layer of endothelial cells, and a layer of subendocardial connective tissue

Clinical relation

16. What is the function of the heart cords and how do the cords perform this function?

The chordae tendineae are a group of tough, tendinous strands in the heart. They are commonly referred to as the “heart strings” since they resemble small pieces of string.

Functionally, the chordae tendineae play a vital role in holding the atrioventricular valves in place while the heart is pumping blood.

17. Which part of the body does the superior Vena cava pump blood to?

The superior vena cava carries blood from the head, neck, arms, and chest.

18. Where is the superior Vena cava positioned?

Your superior vena cava is next to the right side of your sternum and goes into your right atrium, where all the oxygen - poor blood goes.

At the top of the heart

19. Describe two things about the heart that you did not know before conducting the dissection

Learners are expected to provide their own answer and any correct fact about the heart is correct.

Appendix 4: Learner Questionnaires

Please write the number allocated to you on the name space below and feel free to express yourself. The responses are anonymous.

Pseudonym of learner: ___________________

	Simulations	Hands - on
1. Which mode of dissection do you find most effective		
2. Which mode of dissection do you prefer		
3. Please explain what you found most effective about your chosen mode of dissection?		
4. Please explain what you preferred most about your chosen mode of dissection?		
5. Which mode of dissection made you understand the heart better?		
6. With which mode of experimentation did you enjoy participating in more?		

	Yes	Sometimes	No
7. Do you use simulations of dissections in school?			
8. Do you do hands-on dissections in school?			

9. With which mode of dissection did you learn more skills, specify the skills.
10. Is the school equipped to do hands on dissections?
11. Is your school equipped for simulated dissections?
12. Simulations provide the experimenter with added control? Does this control aid or hinder learning in your opinion?
13. In a perfect world what would be the best mode of dissections?
14. Do you believe that simulations are consistently superior to hands on experiments or vice versa, or that both have their advantages and disadvantages?

Thank you for your participation.

Appendix 5: Ethics clearance certificate

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Ismail

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H23/07/14**
PROJECT TITLE	A comparative study between hands-on dissections and ICT simulations (virtual) dissections in Grade10 Life Sciences
INVESTIGATOR(S)	Ms A Ismail
SCHOOL/DEPARTMENT	Wits School of Education/
DATE CONSIDERED	21 July 2023
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	26 September 2026

DATE 27 September 2023 **CHAIRPERSON** ______________________________
(Professor J Watermeyer)

cc: Supervisor : Dr P Kavai

Appendix 6: Turnitin report

turn it in_ A Ismail.docx

ORIGINALITY REPORT

3%	1%	1%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of Witwatersrand Student Paper	1%
2	Submitted to Swiss School of Business and Management - SSBM Student Paper	<1%
3	hdl.handle.net Internet Source	<1%
4	vital.seals.ac.za:8080 Internet Source	<1%
5	Submitted to Student Paper	<1%
6	ttu-ir.tdl.org Internet Source	<1%
7	Christiane Wood, Laurie Stowell, Merryl Goldberg. "Innovation, Literacy, and Arts Integration in Multicultural Classrooms - Theory and Practice for Designers of K-8 Learning Environments", Routledge, 2023 Publication	<1%
8	Biswabhusan Pradhan, Asit K. Mantry. "chapter 4 Designing Effective VR Learning Environments", IGI Global, 2024 Publication	<1%
9	etrr.springeropen.com Internet Source	<1%