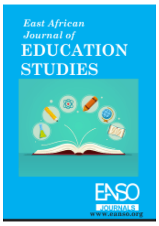


East African Journal of Education Studies
eajes.eanso.org
Volume 8, Issue 1, 2025
Print ISSN: 2707-3939 | Online ISSN: 2707-3947
Title DOI: https://doi.org/10.37284/2707-3947

EANSO
EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Investigating Specific Topic Content Knowledge of Malawian Biology Teachers in Malawi's Schools: A Case Study of Teachers' Lessons on Biotechnology

George Macdonald Vakusi[1] & Assoc. Prof. Nellie Mbano, PhD[2]*

[1] Ministry of Education, P/B 328, Lilongwe 3, Malawi.
[2] University of Malawi, P. O. Box 280, Zomba, Malawi.
[*] Author for Correspondence ORCID ID; https://orcid.org/0009-0007-3795-0690; Email: vakusigm@yahoo.com

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

Date Published:

14 March 2025

Keywords:

Biotechnology, Content Knowledge, Genetic Engineering, Ethical Issues, In-Service Training.

ABSTRACT

Biotechnology focuses on utilizing biological entities to improve people's lives. It is a new topic in the Malawi biology curriculum. This study aimed to investigate the content knowledge of Malawian biology teachers regarding the teaching of biotechnology. Specifically, it explored three objectives: (1) to find out the sources of content knowledge in biotechnology, (2) to find out the level of content knowledge of the teachers and (3) to find out how the teacher's content knowledge impacts on the teaching of biotechnology. The study employed an interpretivist paradigm to gain insights into teachers' experiences in teaching biotechnology concepts. A qualitative research approach using a multiple case study design was employed in this study to allow for the development of a deeper understanding of the phenomenon. A purposive sample was selected from three schools where biotechnology is taught in Form Four classes. Data were collected through a test, interviews and lesson observations to ensure triangulation. Findings revealed that biology teachers heavily rely on single reference textbooks as their primary source of biotechnology content knowledge. As a result, they possess insufficient content knowledge and struggle with understanding key biotechnology concepts, particularly in linking these concepts to students' prior knowledge in genetics and reproduction, hence, their teaching has less impact on students' understanding of biotechnology concepts. The results suggest that biology teachers may benefit from a professional development program focused on enhancing their substantive content knowledge in biotechnology. Consequently, the study recommends further research to explore how biotechnology is interpreted in curricula and textbooks and its overall impact on teaching and learning outcomes.

APA CITATION

Vakusi, G. M. & Mbano, N. (2025). Investigating Specific Topic Content Knowledge of Malawian Biology Teachers in Malawi's Schools: A Case Study of Teachers' Lessons on Biotechnology. *East African Journal of Education Studies*, *8*(1), 508-525. https://doi.org/10.37284/eajes.8.1.2774

CHICAGO CITATION

Vakusi, George Macdonald and Nellie Mbano. 2025. "Investigating Specific Topic Content Knowledge of Malawian Biology Teachers in Malawi's Schools: A Case Study of Teachers' Lessons on Biotechnology". *East African Journal of Education Studies* 8 (1), 508-525. https://doi.org/10.37284/eajes.8.1.2774

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

HARVARD CITATION

Vakusi, G. M. & Mbano, N. (2025) "Investigating Specific Topic Content Knowledge of Malawian Biology Teachers in Malawi's Schools: A Case Study of Teachers' Lessons on Biotechnology", *East African Journal of Education Studies*, 8(1), pp. 508-525. doi: 10.37284/eajes.8.1.2774

IEEE CITATION

G. M. Vakusi & N. Mbano "Investigating Specific Topic Content Knowledge of Malawian Biology Teachers in Malawi's Schools: A Case Study of Teachers' Lessons on Biotechnology" *EAJES*, vol. 8, no. 1, pp. 508-525, Mar. 2025. doi: 10.37284/eajes.8.1.2774.

MLA CITATION

Vakusi, George Macdonald & Nellie Mbano. "Investigating Specific Topic Content Knowledge of Malawian Biology Teachers in Malawi's Schools: A Case Study of Teachers' Lessons on Biotechnology". *East African Journal of Education Studies*, Vol. 8, no. 1, Mar. 2025, pp. 508-525, doi:10.37284/eajes.8.1.2774

INTRODUCTION

In 2013, the Ministry of Education, Science and Technology introduced biotechnology as a new topic in the Malawi secondary school biology curriculum (Ministry of Education, 2018). Biotechnology is a unique and challenging content area that requires advanced cognitive skills due to its application of abstract ideas in developing innovations applicable in industry, medicine and everyday life. For students to grasp the complexities of biotechnology, their teachers must have a solid understanding of the subject. However, many teachers face difficulties teaching biotechnology due to its rapidly evolving nature and the volume of new information (Naz, 2015). The challenge lies not only in content delivery but also in addressing the ethical considerations that accompany biotechnological innovations (Kidman, 2009). The source of knowledge may be textbooks, teachers' guides, in-service teacher education and own reading among the teachers in Malawi.

To enhance teachers' content and pedagogical knowledge in mathematics and science, the Malawi government, in collaboration with the Japan International Cooperation Agency (JICA), launched the Strengthening of Mathematics and Science Secondary Education (SMASSE) project in 2007. This initiative was designed to address poor student performance in mathematics and science, which was attributed to ineffective teaching practices (Chamba, 2009). SMASSE focused on in-service training (INSET) for mathematics and science teachers to improve their instructional methods and, ultimately, student outcomes. Each year, SMASSE trains public secondary school mathematics and science teachers to address challenging topics related to content knowledge, pedagogical skills, and assessment strategies. In 2018, the teachers requested help from SMASSE in teaching biotechnology, especially its content, which showed that most teachers lacked content knowledge.

The challenges with content mastery which were self-reported by the teachers of Biology, prompted the researcher to explore the content knowledge of Biology teachers on the topic of biotechnology. Given that many teachers were not exposed to biotechnology during their own secondary education and may not have encountered it in initial teacher education courses, it became crucial to assess their content knowledge in this area and assess its implications on students' acquisition of biotechnology skills and knowledge as prescribed in the syllabus.

Also, despite the growing importance of biotechnology in science, research on levels and the degree of content knowledge of biotechnology among teachers handling the topic remains limited, with the majority of studies in the field focusing on undergraduate and secondary school students' attitudes and interests in biotechnology as a topic of discussion (Borgerding et al., 2013). The biology curriculum envisions secondary school graduates with a basic understanding of plant and animal breeding strategies, genetic engineering, as well as applications of biotechnology in medicine, agriculture and other industries. Under genetic engineering, students should learn about recombinant DNA technology used in many applications, such as insulin production, and Genetically Modified Organisms (GMOs) among other applications. Apart from studying the concepts, students are also required to be aware of ethical implications and misconceptions about biotechnology and its applications in the real world to minimise misconceptions people have about biotechnological applications (MoEST, 2013).

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

The study aims to find out the sources of content and level of content knowledge of the teachers and how it impacts their teaching. The study sought to answer the following specific research questions:

- What are the teachers' sources of content knowledge in biotechnology?
- What is the level of content knowledge biology teachers have regarding biotechnology and its applications?
- How does the teacher's content knowledge impact the teaching of biotechnology?

Conceptual Framework

Knowledge Bases

Shulman (1986, 1987) identified seven knowledge bases that make a teacher very effective. These are content knowledge; general pedagogical knowledge; curriculum knowledge; pedagogical content knowledge (PCK); knowledge of learners and their characteristics; and knowledge of educational contexts and educational purposes. However, in practice, it is very difficult to separate Shulman's teachers' knowledge bases because they are closely interconnected, especially content knowledge, pedagogical content knowledge, and curriculum knowledge (Maniraho, 2017). According to Shulman (1987), the content taught is selected and organised and is drawn from curriculum knowledge that links subjects and topics, and materials that facilitate such linkage.

Content Knowledge: Source and Impact on Teaching

Shulman, (1986) described content knowledge as the first knowledge base and it includes knowledge of concepts, theories, ideas, knowledge of proofs and evidence as well as practices and approaches to develop this knowledge. Shulman (1986) defined content knowledge as the knowledge, understanding, skill, and disposition that are to be learned by students. Different researchers have given different definitions of content knowledge, but all agree that content or subject matter knowledge is the knowledge of facts and concepts and understanding of the structure of a subject. Barış, & Kırbaşlar, (2015) argue that a teacher's content knowledge of a subject or topic is very important because high-quality teaching depends on the teacher's understanding of the subject or topic they are teaching. Kind (2014) claims that teachers' abilities to teach different topics and concepts of science are affected greatly when the teacher has weak subject-specific content knowledge, hence the need for a teacher to have very good knowledge of every topic in the subject he/she teaches. According to Hill & Luft (2015) and Ramli et al., (2019), many researchers have found that teachers with higher content knowledge are more appropriate to increase student learning in their area of expertise because they support students better in developing more accurate conceptions of science. Therefore, teachers with good content knowledge tend to have an impact on their teaching.

Many studies have been conducted to define the content knowledge and other knowledge bases that a teacher in different subjects such as Mathematics, Chemistry, and Biology and specific topics within the subjects must possess (Moreland et al., 2006; Ball et al., 2008; Mthethwa-Kunene et al., 2015; O'Brien, 2017). All these studies have based their models on the work initiated and inspired by Shulman.

Ball et al., (2008) improved Shulman's work, particularly about teachers' content knowledge. Although they focused on mathematics, where they distinguished content knowledge into common content knowledge and specialised content knowledge. According to Ball et al. (2008), specialised content knowledge is defined as 'the mathematical knowledge and skill unique to teaching'; common content knowledge is "mathematical knowledge that is also used outside of the teaching context". Ball et al., (2008) conceptual framework tries to find a broader field of research on teacher knowledge. Ball et al (2008) identified teachers' content knowledge as an 'uncharted area' (p. 402), which has not been subject to empirical research. Bruns et al., (2021) agreed with Ball et al., (2008) by stating that specialised content knowledge, which is only relevant in the teaching context, is naturally not part of formal teacher education.

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

METHODS

This study used the interpretivism paradigm to understand biology teachers' experience as they teach biotechnology concepts. Interpretivism makes it easier to understand and interpret participant teachers' thoughts and decipher the phenomenon's meaning at hand (Kivunja, & Kuyini, 2017). A qualitative research approach using a multiple case study design was employed in this study. This approach allowed for the development of a deeper understanding of the phenomenon by examining multiple cases, providing richer insights than a single case could offer (Creswell, 2012). Three participants were drawn from both rural and urban public secondary schools within the Lilongwe district.

Participants of the Study

The research study involved three teachers in three different schools who were purposefully selected. At the time of the study, the teachers were teaching biotechnology and had more experience in teaching biology. The teachers differed in terms of educational qualification and the teaching subjects though the number of years for teaching biotechnology was the same, Table 1.

Table 1: Profile of Teachers

Participant	Teaching experience	Years taught biotechnology	Qualification	School type	Major teaching subjects	Subjects currently teaching
Joseph	15 years	2	Bachelor of Education	CDSS **X**	Biology and Chemistry	Biology and Chemistry
John	12 years	2	Diploma in Education	CDSS **Y**	Mathematics and Biology	Biology and Agriculture
James	13 years	2	MSCE	CDSS **Z**	No specific subject	Biology and Mathematics

Though Table 1 shows different characteristics in terms of their qualifications and experience, the teachers were only identified as form four biology teachers. One teacher had a bachelor's degree in education specialised in biology and chemistry and he was teaching the same subjects during the study period. The second participant had a diploma in education and had specialised in biology and mathematics, but he was teaching biology and agriculture during the study period. The third participant had a primary school teaching certificate and the Malawi School Certificate of Education (MSCE). All the three participants may lack biotechnology content.

To find out the level of content knowledge of the teachers, the first author gave the participants a biotechnology test and observed the three teachers in two lessons respectively on biotechnology and thereafter transcribed the lessons as part of his studies for his PhD studies.

Data Collection

To create a comprehensive description of each teacher's content knowledge, data were collected through a test, interviews and classroom observations. Creswell (2014) refers to this process as utilizing "multiple sources of information." Wilson et al., (2018) note that teachers' professional knowledge, including content knowledge, is reflected in their work and involves planning, instruction, and reflection. In this study, biotechnology tests, interviews and lesson observations were the primary tools used. According to McConnell et al., (2013), these tools are effective for assessing and understanding content knowledge, though they are time-intensive.

Biotechnology Test

To investigate the biology teachers' content knowledge on the biotechnology topic, one of the instruments developed was a test based on the MSCE biology curriculum content developed by the researcher. The suitability of the item format, such as the use of closed-item questions like multiple-

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

choice items or open-ended item questions, is one of the issues raised by using a test to assess teachers' content knowledge (Schmelzing et al., 2013). According to Schmelzing et al. (2013), the closed item structure creates issues with formulating and assessing accurate responses as well as distractions. Contrary to closed items, open-ended questions offer a chance to assess teachers' unique content knowledge on a specific topic (Schmelzing et al., 2013; Juttner et al., 2013). Therefore, the test developed had open-ended questions.

The test had nine (9) questions which had mixed levels starting from recall to comprehension questions. The first question asked the teachers to state the advantages of hybrid maize and how artificial cross-pollination is done. The second question asked the teachers to give three types of microorganisms used in the manufacturing industry and products produced by fermentation by yeast. The third question asked teachers to simply define genetic engineering and recombinant DNA and also differentiate a clone from a transgenic organism. The fourth question asked them to name the enzyme that joins DNA fragments, and the location of plasmids and give a reason why restriction enzymes are called molecular scissors. Question five asked the teachers to simply name any two proteins and two enzymes obtained by recombinant DNA technology. The sixth question asked the teachers to explain how recombinant DNA technology is useful for pharmaceutical companies. The seventh question asked teachers to state any two diseases whose vaccines are bioengineered. The eighth question asked teachers to describe three usefulness of transgenic organisms and they should mention two methods used in the production of these organisms. Then they should describe any one method. This was a question that required the teachers to describe the method of producing transgenic organisms. The last question requested teachers to describe any three ethical implications of biotechnology on society.

The biotechnology test was reviewed by two biology education specialists to find out if the test items were consistent with the MSCE curriculum success criteria. Before the test was administered, it was piloted using 5 biology teachers from public secondary schools. The teachers used during the pilot phase were selected using the same criteria as the participants of the study. Feedback from the education specialists and the biology teachers was used to improve the test.

The biotechnology test was administered to the biology teachers in their respective schools and they were allocated 45 minutes to complete the test. If the teacher's answer was acceptable, it was coded right and on the other hand, if the teacher's answer was wrong or lacked some scientific information it was coded wrong.

Interviews

Two semi-structured interviews per lesson observed were conducted to assess teachers' knowledge. The first interview, held before the lesson, focused on how teachers planned to teach the content. The second interview, conducted immediately after the lesson, explored teachers' reflections on their instruction. Semi-structured interviews were chosen for their flexibility, allowing the interviewer to follow a guide with specific questions while adapting to the interviewee's responses (Bailey, 2007). Pre-lesson interviews assessed lesson planning, with Zaare (2013) highlighting that such interviews reduce anxiety and provide insights into how the teacher plans to approach the lesson. Post-lesson interviews, along with document analysis of lesson plans and student work samples, were used to triangulate the data and provide reflection measures.

Lesson Observation

Lesson observation is a qualitative data collection method where the researcher immerses themselves in the research setting to observe first-hand behaviours, interactions, and social actions (Creswell, 2014). Classroom observation provided critical insights into teachers' content knowledge and how they delivered biotechnology lessons. The focus was on the content taught, how teachers interacted with students, and their use of prior knowledge during instruction. The observation also recorded students' questions, teachers' responses and feedback.

With participants' consent, all lessons were video recorded. Two lessons per teacher were recorded to ensure data saturation. The observation data were

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

transcribed, and field notes were taken to document the classroom environment, teacher-student interactions, and teacher explanations. Aydemir (2014) emphasizes the importance of such data for accurately reconstructing classroom events.

Ethical Considerations

Permission was sought from different authorities before data was collected. These included the University of Malawi, the Ministry of Education and heads of institutions where both the piloting and the main study were conducted. The teachers were informed that their identities would be kept confidential including their schools by using pseudonyms.

Data Analysis

The data generated through the test, interviews and transcribed lesson observations was carefully scrutinised and organised to address the study's research questions. The data generated from the three Form Four biology teachers was systematically analysed to answer the study's three specific research questions, utilising the test, interviews and lesson observations, to gain comprehensive insights into the teachers' content knowledge.

FINDINGS OF THE STUDY

Sources of Content Knowledge

When asked about the resources used for planning and preparing biology lessons on biotechnology, Joseph revealed that he relied on a single textbook, *Njolinjo* (2014), as his primary source of information apart from the syllabus. He noted that this textbook had rich content on biotechnology, which made it his preferred choice. When asked about the challenges he anticipated in teaching biotechnology, Joseph highlighted the lack of adequate teaching and learning materials as a significant obstacle.

James, on the other hand, used multiple resources, including four different recommended textbooks, the syllabus, internet resources, and materials from the SMASSE Inset, to plan and prepare his lessons. Unlike Joseph, James consistently wrote lesson plans, which helped him maintain focus and structure throughout his lessons. When asked about potential challenges, James identified difficulties in understanding genetics as a major issue that could affect his ability to teach biotechnology concepts effectively.

John, similar to Joseph, also relied on the *Njolinjo* (2014) textbook as his sole resource for planning and preparing biotechnology lessons. He did not write lesson plans, citing a heavy workload as a hindrance. However, John expressed confidence that his students would be able to grasp biotechnology concepts by building on their prior knowledge of plant and animal breeding, which they had learned in Form 3 agriculture lessons.

Biology Teachers' Understanding of the Content Knowledge from the Test

The biology teachers' understanding of biotechnology was investigated firstly with the help of a biotechnology test and the results of each teacher were described and analysed separately. Analysis of the teachers' biotechnology test indicated that Joseph scored 79%, James 90%, and John 67% respectively. Analysis of each teacher's test paper question by question, showed that the teachers had different problems in certain subtopics of biotechnology as discussed in the section that follows.

Joseph's Understanding of Biotechnology from the Test

The analysis of Joseph's answers to the first question showed that he was able to state the advantages of hybrid maize and how artificial cross-pollination is done. In the first part of the second question, he correctly gave the three different kinds of microorganisms used in the manufacturing of industrial products but failed to mention the products of industrial fermentation by yeast in the second part of question two. He responded that carbon dioxide, alcohol (ethanol), and energy are products produced through fermentation. The expected answers did not include energy because it is not an industrial product. This showed that he simply stated the products of anaerobic respiration done by yeast. However, in the third part of question three where he was asked to define recombinant DNA, Joseph provided a misleading definition. Joseph's definition was "recombinant DNA is a gene formed by joining two DNA segments from two different sources". This is a wrong definition because he defined DNA as being a gene instead of sections of genes from different sources combining to form DNA. This shows that Joseph had a problem understanding the relationship between genes, DNA, and chromosomes arising from the topic of genetics which he had taught followed by evolution before teaching biotechnology.

The fourth question had three parts. Joseph answered the first and third parts well but failed to give a clear answer to the second part which asked why restriction enzymes are called molecular scissors. His answer stated, "Because they degrade the bacterial chromosome in small pieces during replication". His response meant that restriction enzymes destroy chromosomes which is not correct instead of stating that these enzymes snip chromosomes at precise points making it possible to cut out a gene from a chromosome. Similarly, Joseph managed to mention one protein but could not state the two enzymes obtained by recombinant DNA technology respectively which were asked in the fifth question. Joseph was able to answer questions six and seven very well which asked him to explain how recombinant DNA technology is useful for pharmaceutical companies and to mention two diseases whose bioengineered vaccine has been developed respectively. Joseph also performed well in all three parts of question eight. The last question asked him to describe any three ethical implications of biotechnology on society.

Joseph demonstrated good knowledge of the content as prescribed in the syllabus. He was able to answer the questions related to four of the success criteria (objectives) provided in the syllabus. These include: students being able to give examples of animal and plant breeding; describing the process of genetic engineering, discussing other applications of genetic engineering and ethical implications of the use of biotechnology. However, he failed to provide concrete responses to three questions which were related to two success criteria which asked students to describe the applications of biotechnology and genetic engineering respectively. Firstly, he confused the anaerobic respiration of yeast with industrial products that use the fermentation process. Secondly, he failed to show the relationship between a gene, DNA, and chromosome by stating that recombinant DNA is a gene formed by joining two DNA segments and finally, he could not give a reason as to why restriction enzymes are called "molecular scissors".

James' Understanding of Biotechnology from the Test

James' responses showed that he had good content knowledge of biotechnology as he could provide the most correct answers on all nine questions compared to the other two teachers. However, on the first question which had two parts, he answered very well on both parts. In the second question, the first part he stated bacteria, yeast and moulds. Yeast and moulds fall under fungi. Therefore, James was given two marks instead of three for fungi and bacteria as the microorganisms used in the manufacturing of industrial products. The second part of question two was correct. All the products he mentioned are produced on a large scale. For questions three and four respectively, James provided answers that matched the correct answers.

On question five, he was able to provide the correct proteins and enzymes that are produced by recombinant technology as found in the recommended biology textbooks. On the sixth question, he was able to explain how recombinant DNA technology is useful for pharmaceutical companies and he was able to mention two diseases for which bioengineered vaccines have already been developed as "Rabies and Hepatitis B" as it was asked in question seven. In the eighth question, which had three parts, James was able to respond correctly to the first and second parts. However, in the third part of the question, James could not describe the method fully as he defined it and gave reasons why it is important and its implications to human society instead of providing the process. James clearly provided the correct responses on the ethical implications of biotechnology on society.

In summary, James was able to answer almost all the questions which covered all the six success criteria in the syllabus. However, he could not mention one group of microorganisms, viruses which are also used in the production of industrial products and he

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

could not describe how embryonic stem cells are used.

John's Understanding of Biotechnology from the Test

John had more problems answering some of the questions compared to James and Joseph respectively. John had mixed knowledge of the advantages of hybrid maize. He could not give straightforward answers to the two parts of the first question. The first part of question one demanded three advantages of hybrid maize. He simply stated that the hybrid maize yields twice as much without specifying the local varieties available in Malawi which he would have compared with. On the second answer, he was given a mark because he mentioned an insect which was treated as a pest. The last advantage was marked wrong because the resistance to herbicides is developed after genetic engineering resulting in the development of a Genetically Modified maize and not hybrid maize according to Chimocha, & Lungu (2017), one of the recommended biology textbooks. On the second part of question one, he could not provide the correct answer because the question starts from the stem of the question which states that hybrid maize is produced by artificial cross-pollination, therefore, John was supposed to describe artificial cross-pollination of maize and not the general cross-pollination he provided.

In the first part of the second question, he stated bacteria, fungus and moulds as the microorganisms used. He was given two marks because moulds are a type of fungus. In the second part of question two, he was given two marks also because scones and local bread were taken as the same. Therefore, cheese and bread were taken as the correct answers. In question three the answers he provided matched with the correct answers. Similarly, for question four, John provided correct answers. On question five, the two proteins he provided were correct though they are not found in either the curriculum or recommended textbooks. The proteins he stated were above MSCE level while the enzymes he provided were marked wrong because the first one, restriction enzyme is a general term while *alkaline factitase* does not exist as far as the content of biotechnology was searched. Similarly, on question six John failed to explain how recombinant DNA technology is used in pharmaceutical companies. On question seven, John correctly stated Covid-19 was a disease whose vaccine had been bioengineered already and was given a mark while on HIV he was wrong because, then there was no vaccine for HIV at the time of the study.

Question eight had three parts where John provided different responses. In the first part, the question demanded three uses of transgenics. Out of the three he provided only the first two were marked correct though seemed to be similar to the production of insulin and the production of hormones as insulin too is a hormone that treats a disease, diabetes. The last response was completely wrong. In the second part of the question, John correctly stated the methods used in the production of transgenics. However, in the last part of the question, John defined the method instead of describing the process as the question demanded.

The last question asked him to describe any three ethical implications of biotechnology on society. John's responses did not match with the provided correct answers. John simply wrote the same answer in different ways as he was describing how biotechnology could interfere with nature while the second answer was vague as there is no scientific backing that transgenic cows do die if they are not milked due to too much milk they produce. This information was provided by Njolinjo (2014) as possible topics for debate as a class activity and John took the statement to mean "Cows bred for milk die when they are not milked". Therefore, John got one response correct out of the three responses.

In summary, John had problems answering questions from many success criteria in the biotechnology topic. These include the first success criteria which state that students must be able to give examples of plants and animal breeding in Malawi, describing the applications of biotechnology, the process of genetic engineering and the ethical implications of the use of biotechnology. Comparing the three teachers, it was concluded that John had the lowest content knowledge based on the test result.

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

Joseph's Level of Content Knowledge Based on Lessons Observed

Joseph began his first lesson by engaging students with real-life examples of biotechnology. He presented two packets of hybrid maize seeds, explaining that they were products of biotechnology, thereby connecting the topic to something familiar in the students' everyday experiences. He extended this connection by explaining that certain animals and their products also result from biotechnological processes. This approach helped contextualize biotechnology and made the lesson more relevant to the students.

Joseph used a participatory approach to introduce the term "biotechnology." He asked students to brainstorm definitions, prompting a class discussion. Students offered varied responses, such as:

> *"It is the process of changing some existing organisms to become one with an aim of improving products."*

> *"It is the process of reintroducing some varieties to come up with desirable characteristics."*

Joseph refined these responses and then provided a clear definition of biotechnology. He defined biotechnology as *the use of living organisms and their body systems to develop new and useful products that help to improve human life.* Throughout the introduction, too, Joseph addressed several abstract concepts, defining them clearly with practical examples. He covered Biotechnology, Genetic Engineering, DNA Molecule and Recombinant DNA. He gave clear and elaborate definitions of these terms.

The lesson was structured effectively, beginning with concrete examples before moving into more abstract concepts. Joseph connected new content to students' prior knowledge of genetics and successfully introduced terms such as **Recombinant DNA**, which he explained as the ability to combine DNA from different organisms. He also introduced the concept of **genetic engineering**, explaining how scientists alter the DNA code of organisms using microorganisms like bacteria and viruses. Next, Joseph introduced methods for improving plant and animal breeds, starting with **hybridization**, which he defined as the crossing of different species to improve them. Unfortunately, he incorrectly cited **Bt. Cotton** in an example of a hybrid crop in Malawi, stating it was produced by the Lilongwe University of Agriculture and Natural Resources (LUANAR). In reality, Bt. Cotton is a genetically modified organism (GMO), introduced by Monsanto and tested by LUANAR. Despite this error, Joseph accurately explained the concept of **GMOs** (genetically modified organisms) and **transgenic organisms** but failed to provide relevant local examples. He had the theoretical knowledge but failed to provide practical examples. He did correctly cite local research stations, such as Chitedze and Makoka, where hybrid crops are developed, but his focus on these locations detracted from the lesson's objectives. His discussion of animal breeding, however, was more successful, with examples such as cattle and chickens being explained clearly.

Joseph began the second lesson by reviewing the previous lesson. He asked students to recall the definition of biotechnology and its applications. Thanks to a homework assignment, students responded well, citing applications such as **forensic science**, **blood transfusion**, and **plant and animal breeding**. Joseph then introduced the topic of **genetic engineering** and asked students for a definition, which they attempted with some success.

One student defined genetic engineering as *"a process whereby a gene is transferred by human manipulation,"* which Joseph refined further as "*the process of manually adding a gene into the DNA of an organism.*" He reiterated the concept of recombinant DNA and provided a clearer definition, noting that it involves DNA that has been altered by adding a gene from another organism.

Joseph introduced the term **transgenic organism**, defining it as "an organism whose DNA has been added an extra gene or has been altered." His explanation of the difference between recombinant DNA and transgenic organisms, however, lacked clarity. Ideally, he should have clarified that recombinant DNA is a specific genetic material created during genetic engineering, while a transgenic organism is one that has been genetically modified with recombinant DNA.

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

Later in the lesson, Joseph discussed microorganisms used in genetic engineering, highlighting bacteria and viruses, with a focus on bacteria. He referenced students' previous knowledge of bacteria but did not provide visual aids, such as diagrams, to reinforce his explanations. He introduced the term **plasmid**, explaining its role in genetic engineering but failed to define it clearly or compare it to chromosomes, leading to some confusion. He showed a chart with sketchy diagrams of plasmids and chromosomes but did not explain the details effectively, leaving students uncertain.

In conclusion, Joseph demonstrated a solid understanding of the core concepts in biotechnology and genetic engineering but struggled to explain certain technical terms, such as plasmids and transgenic organisms. His use of practical examples, such as hybrid maize seeds, was effective in contextualising the material, but time management and clarity in defining scientific concepts were areas for improvement. Additionally, his occasional misinformation (e.g., regarding *Bt*. Cotton underscores the importance of accurate content knowledge in teaching complex scientific topics.

James' Level of Content Knowledge Based on Lessons Observed

James began his first lesson on **animal and plant breeding** by reviewing students' prior knowledge of genetics. He probed their understanding of genetic variations among organisms before introducing the lesson topic, **biotechnology**. James then asked students to brainstorm the meaning of biotechnology. James consolidated their suggestions and defined biotechnology as *"the utilization of organisms, their parts, or their processes to produce organisms or products that benefit humans."*

He then wrote the discussion topic, **Animal and Plant Breeding in Malawi**, on the board and then asked the students to be in groups. Using the textbooks he provided, he tasked them to identify different varieties and other crops produced by different companies and later asked them to present

In summarising the topic, James explained how plant and animal breeding works. He noted that hybrid seed production is widespread in Malawi, with many companies breeding plant species, particularly maize. He explained that maize breeding focuses on producing early maturing, high-yielding varieties suited for small cultivation fields. Regarding animal breeding, he discussed crossbreeding practices in Malawi, using **Black Astro poultry** as an example. He described how this breed is crossbred with local poultry to combine traits like larger size and higher egg production with the local breeds' disease resistance and adaptability to the environment. He also discussed crossbreeding in dairy cattle, where exotic breeds are mixed with local ones to improve milk yield and disease resistance. Notably, all the content James presented in this lesson aligned with the approved textbooks.

In the second lesson, James began by reviewing the content from the previous session using a **question-and-answer method**. The students struggled with the review questions on plant and animal breeding and the applications of biotechnology. To help, James used probing questions and corrected misconceptions, such as clarifying that **yeast**, not bacteria, is used in beer brewing.

James then introduced the day's lesson on **genetic engineering**, aiming to teach students how to describe the process. He asked the students to brainstorm a definition of genetic engineering, but none could provide one. To address this, he organised them into pairs to suggest definitions. From these discussions, four definitions were proposed, which James then consolidated into an accurate explanation.

After defining genetic engineering, James organised the students into groups, assigning each group a section of the textbook that described the process. He instructed them to summarize the steps involved, including the tools used. The groups then presented their summaries in class. While the first two groups made similar presentations, both contained errors regarding the sequence of steps. To correct this, James posted a chart illustrating the correct process on the chalkboard. He emphasized that **bacteria** are often used in genetic engineering due to their rapid multiplication and the presence of **plasmids**, which play a key role in the process.

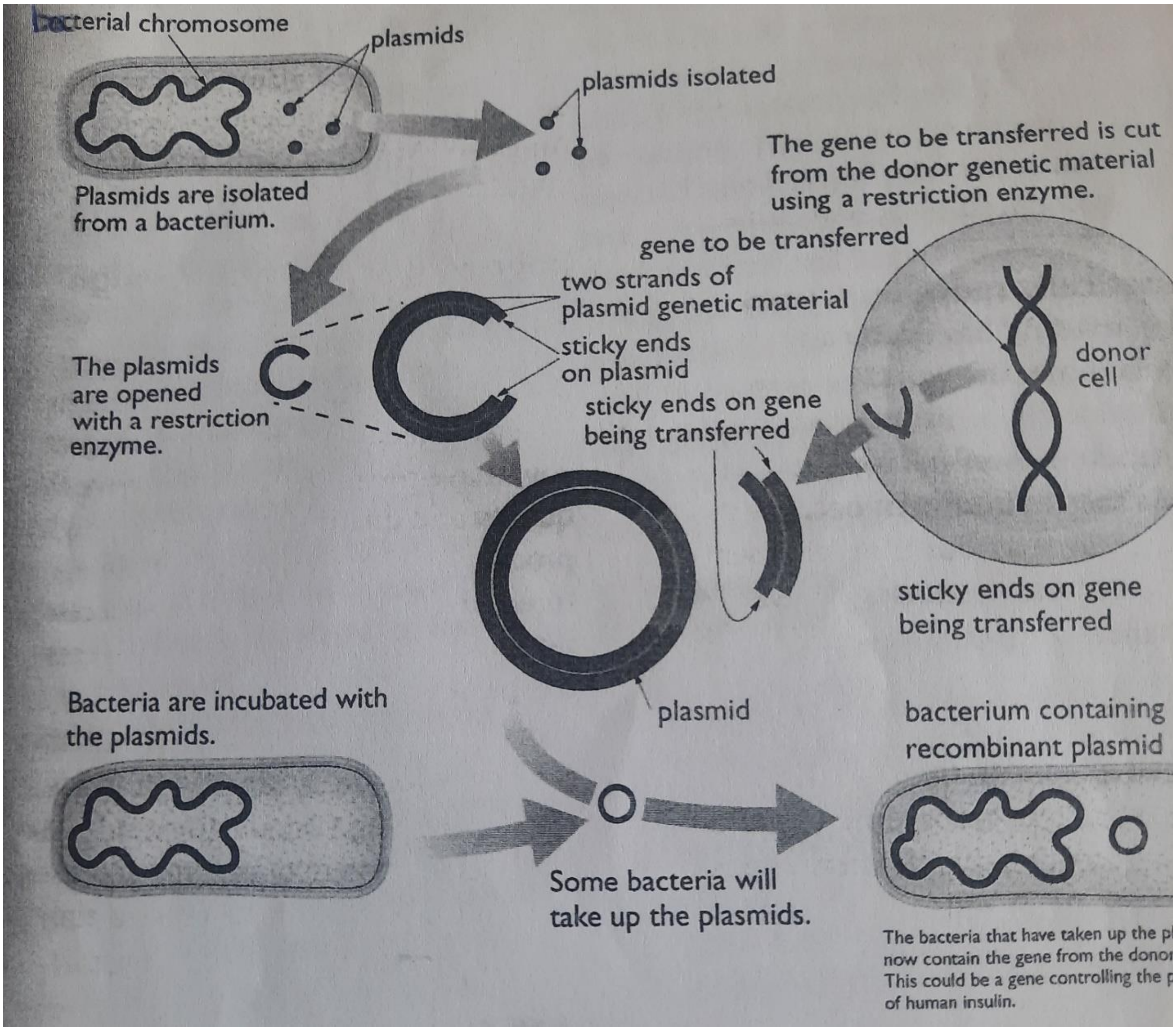
James proceeded to describe the process of genetic engineering, using the example of high-yield crop

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

traits. James concluded the lesson by summarizing the process of genetic engineering, emphasizing its practical applications and the role of genetic modification in improving agricultural production.

James effectively utilized a clear and well-labelled chart (Figure 2) from Avis et al. (2018) to illustrate the stages of producing a transgenic bacterium. He accurately identified key tools used in genetic engineering, including cell structure, restriction enzymes, plasmids, host bacteria, and ligase.

Figure 1: Diagram *S*howing the *P*rocess of *G*enetic *E*ngineering (Stages of *P*roducing a *T*ransgenic *B*acterium.



Source: Avis et al, 2018, pp 133

However, at one point, he introduced a concept not prescribed in the syllabus—**T-DNA**—without providing any explanation. This introduced unnecessary complexity, particularly given the students' level of understanding. Some students also struggled with understanding the role of **molecular glue** (ligase) despite James's detailed explanation using the chart. To help students grasp the concept, James implemented a practical analogy: he cut a piece of paper to represent the plasmid and another piece to symbolize foreign DNA, then used glue to attach the second piece to the first. He compared this to the genetic engineering process, explaining how ligase seals foreign DNA into the plasmid, ensuring the two ends fit together. In his summary, James walked the students through the entire process of genetic engineering once more, then introduced the next lesson on **insulin production** and other applications of biotechnology.

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

In both lessons, James demonstrated a solid understanding of the subject matter, effectively guiding students through complex topics. He was well-organised and maintained good classroom control, aided by well-prepared lesson plans. He consistently began lessons by reviewing prior content, ensuring continuity and reinforcing students' understanding. For example, he reviewed the previous lesson on genetic variations, linking it seamlessly to the new topic of biotechnology. By leveraging students' prior knowledge, he guided them to the current lesson objectives.

Fostering engagement, James supported learning with concrete examples and visual aids. He used a chart (Figure 1) to explain genetic engineering and employed practical analogies, such as cutting and glueing paper, to clarify complex processes like the function of ligase. He was also adept at addressing misconceptions, using concrete examples to correct students' misunderstandings.

Also, although James displayed strong content knowledge and communication skills, there were some gaps. He failed to clearly differentiate between certain concepts, such as plasmids and chromosomes, which could have hindered student understanding. Additionally, by introducing content beyond the prescribed curriculum (such as T-DNA), he risked confusing students. Despite these issues, James demonstrated a significantly better grasp of biotechnology concepts compared to Joseph.

John's Level of Content Knowledge Based on Lessons Observed

John began the first lesson by discussing hybridisation but quickly moved on to genetic engineering, only to return to basic genetics concepts (such as DNA and chromosomes). This disjointed approach confused students, making it difficult for them to follow the lesson. Additionally, he spent an excessive amount of time revisiting genetic terms from previous lessons.

Another challenge John faced was in the clarity of his communication and interpretation of key concepts. He struggled to clearly define and differentiate between hybridisation and genetic engineering, and he introduced advanced topics like gene recombination, DNA code, and DNA transcription without providing adequate context or definitions, further adding to students' confusion. Mentioning DNA transcription was particularly problematic, as it falls outside the secondary school curriculum and is inappropriate for the MSCE level.

The researcher also noted inconsistencies in student engagement. For example, John initially asked students to define biotechnology terms but failed to sustain this interaction throughout the lesson. He abruptly ended the class without allowing time for students to discuss the assigned questions, missing an opportunity for meaningful engagement and peer learning.

Furthermore, John frequently deviated from the curriculum. He did not adequately describe hybridization as required and introduced complex concepts not included in the secondary school syllabus, such as DNA transcription. This lack of focus on the lesson's success criteria resulted in a scattered and unfocused teaching approach.

However, there were noticeable improvements in the second lesson. John effectively structured the revision process by starting with a recap of the previous lesson and facilitating discussions on the advantages and disadvantages of hybridization. Student engagement also improved; he encouraged students to write their answers on the chalkboard, fostering better interaction. Additionally, John provided clearer explanations of concepts in the second lesson compared to the first, encouraging students to list the pros and cons of hybridization, which enhanced their understanding.

John effectively explained how hybridisation can improve the adaptability of plants and animals to various conditions. He used examples to illustrate how gene introduction from one organism to another can enhance adaptability in different environmental contexts. However, he struggled to explain how gene complexities could serve as a disadvantage of hybridisation, particularly in terms of disease transmission. He accepted the advantages and disadvantages listed by students without further critical analysis or correction.

During the lesson, John read a passage from a textbook discussing genetically modified organisms (GMOs) and hybrids. He cited Bt. Cotton produced

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

in Malawi as an example of a transgenic plant and highlights the significance of biotechnology in improving crop yields and product quality. While he addressed student inquiries about cross-breeding plants, gene transfer, and gene presence, his explanations were basic and lacked depth. For instance, he mentioned cross-pollination without detailing the methodology, and although he referred to injectors for gene transfer, he did not elaborate on the specific techniques involved. Furthermore, while he affirmed the existence of genes in plants, he did not clarify their location or structure.

Overall, John's lessons displayed some strengths in engaging students and attempting to discuss the content. However, significant challenges remained in his ability to communicate complex concepts clearly and provide detailed explanations. His reliance on reading from the textbook and accepting student responses without critical evaluation indicated a need for stronger content knowledge and instructional skills.

In summary, the lesson observations revealed significant problems with John’s content mastery of biotechnology. He incorrectly equated biotechnology with recombinant DNA in his first lesson and mislabelled the lesson topic as "hybridization" instead of "plant and animal breeding," which is the correct term according to the syllabus. He also mistakenly asserted that maize varieties are improved through "gene recombination" and referenced "DNA transcription," concepts that are too advanced for the MSCE level.

John's handling of student questions further illustrated his weaknesses in biotechnology content mastery. When asked how cross-breeding is performed, he provided a basic overview of cross-pollination rather than a detailed description of artificial cross-breeding, demonstrating limited knowledge in this area. Students' pressing questions about gene transfer and gene locations indicated gaps in their understanding of previously taught genetics concepts. John's brief and vague answers likely did not clarify these topics for the students. Despite these shortcomings, he did correctly define hybridization as cross-breeding and provided mostly accurate examples, though he occasionally introduced incorrect or irrelevant information.

John's lessons suffered from inadequate planning and structure, leading to disorganised content delivery. He did not sufficiently prepare to ensure that students understood foundational concepts before introducing more complex ideas. His assumption that students were familiar with the content being taught likely contributed to the observed confusion.

The frequent confusion of concepts and John's inability to provide clear, accurate explanations signal serious issues with his content knowledge and mastery. His failure to adequately address student inquiries and his reliance on an erroneous textbook demonstrates a lack of comprehensive understanding of the subject. Moreover, introducing advanced genetic concepts that are not part of the curriculum highlights a misunderstanding of the appropriate content level for secondary school students, revealing gaps in his grasp of both the curriculum and suitable content for his learners. The overreliance on a single flawed textbook exacerbated these problems related to biotechnology instruction.

DISCUSSION OF STUDY FINDINGS

The findings show that most teachers use single sources of content knowledge despite the Ministry of Education providing at least four different recommended textbooks including the syllabus. This was exhibited by Joseph and John. This is in agreement with the study by Mthethwa-Kunene et al., (2015) in Eswatini which found that teachers depend on a single textbook, the syllabus as the major source of information. This causes the teachers to have low content knowledge of the topic because a single textbook cannot provide all the necessary content for students to understand the concepts. In Malawi, it is common for teachers to rely on a single source for lesson preparation, often choosing textbooks rich in content but lacking in activities or assessments. While this reflects a focus on content knowledge, it neglects the necessary pedagogical strategies for effective student communication, which are crucial for quality learning. This trend is often influenced by a greater emphasis on examination success rather than

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

genuine learning (Sakala, 2013). However, what James demonstrated showed that sourcing information from different textbooks and other sources enriches the teacher's content knowledge which ends up impacting well on his teaching.

Similarly, James' performance in the test shows that he had a better understanding of the different concepts of Biotechnology because he read widely. The same is exhibited in the lesson observations which that he had a strong grasp of biotechnology content, surpassing both Joseph and John. His thorough understanding was also evident in the pre-lesson interviews, where he clearly articulated the material he intended to teach. Throughout both lessons, James demonstrated a solid knowledge base by effectively explaining abstract concepts and processes in biotechnology. James' strong content knowledge can largely be attributed to his consistent attendance at SMASSE In-Service Trainings in Biology and his comprehensive lesson preparation. He frequently gathered and consolidated information from diverse sources, which is supported by empirical research indicating that teachers who regularly engage in in-service training benefit from enhanced content knowledge and pedagogical skills (Mphathiwa, 2015), a study which was done in Botswana. Studies have shown that biology teachers reporting low content knowledge often cite a lack of in-service training as a contributing factor (Srutirupa, & Muhalik, 2013). Furthermore, a teacher's propensity to explore multiple information sources during lesson preparation has been linked to higher content knowledge (Zhao, & Fan, 2022). His organised lesson plans and clear articulation of complex concepts reflected his depth of understanding.

Joseph ranked second in content knowledge, possessing a relatively strong grasp of biotechnology. However, he occasionally provided incorrect information in both the test and in the lessons. During the pre-lesson interviews, Joseph articulated his intended concepts well, but this clarity did not carry over into his teaching. For instance, he mistakenly described a plasmid as "a part in a bacterium specialized for multiplication," whereas a plasmid is a small circular DNA strand that can replicate independently of chromosomal DNA (Ministry of Education, 2018). While he correctly described chromosomes as structures containing DNA, his errors indicated a lack of thorough preparation. The use of only one textbook for his lesson preparation affected his understanding of content and effectiveness in the teaching of biotechnology concepts.

John ranked last in terms of content knowledge. This was exhibited both in the test and in the lessons observed. Although he initially articulated his planned content well during the interviews, he struggled to convey concepts during the lesson. His reliance on reading directly from the textbook without providing further explanation demonstrated a lack of mastery over the material. For example, John was unable to explain how recombinant DNA technology is applied in the pharmaceutical industry or discuss the ethical implications of biotechnology. Moreover, his use of confusing terminology, such as describing gene transfer as "injected," further muddled students' understanding. John's knowledge gaps severely hindered his students' ability to master and appreciate the significance of biotechnology. Teachers with substantial knowledge deficiencies often convey inaccurate information, which perpetuates students' misunderstandings (Käpylä et al., 2009). John's frequent use of incorrect terminology reflects inadequate research during lesson preparation, aligning with findings that suggest teachers who use imprecise vocabulary typically lack sufficient preparation (Borgerding et al., 2013). His reliance on a single textbook negatively impacted his content mastery, as research shows that comprehensive use of the biology syllabi and recommended textbooks enhances teachers' content knowledge and pedagogical content knowledge (PCK) (Mthethwa-Kunene et al., 2015; Özden, 2008).

The expectation was that all teachers would easily meet the first success criterion, as the concepts were directly linked to previously taught genetics topics and were less abstract than other success criteria. Teachers were anticipated to connect this topic to genetics and provide examples of animal and plant breeding. However, both Joseph and John treated plant and animal breeding as separate concepts, failing to integrate them with genetics. Teaching

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

genetic engineering, which is more abstract, could have been enhanced through the use of illustrations or physical models to facilitate student understanding. Additionally, linking genetic engineering to foundational concepts like plasmids, chromosomes, genes, and DNA would have reinforced students' comprehension. Establishing relationships among these concepts before introducing genetic engineering processes would have helped students grasp terms such as recombinant DNA and transgenic organisms, clarifying their connections to genetics and biotechnology.

The participant teachers displayed varying levels of content knowledge, influenced by several factors, including their academic backgrounds. Both Joseph and John are biology majors, with Joseph holding a degree and John a diploma. Despite their educational qualifications, neither had studied biotechnology in their pre-service training and had attended SMASSE in-service training in other subjects. Their reliance on a single textbook (Njolinjo, 2014) and the absence of lesson plans highlighted inadequate preparation and content mastery, leading to a tendency to read directly from the textbook in class without checking for student understanding.

In contrast, James, despite lacking formal qualifications, demonstrated strong content knowledge due to his attendance at biology-focused SMASSE in-service training, use of multiple textbooks, and diligent lesson planning. His commitment to thorough research and lesson preparation significantly improved his teaching effectiveness and content delivery.

The differences in teaching effectiveness among the three teachers can thus be attributed to their varying levels of content knowledge, preparation, and commitment to ongoing professional development. James's proactive approach to professional growth and lesson planning allowed him to effectively convey complex topics, distinguishing him from Joseph and John. In this study, academic qualification was insignificant.

A small sample size of participating teachers and students who did not participate were among the study's limitations, which resulted from the lack of resources. The study's findings have important implications for biology teachers, academics, and curriculum developers regarding the biology teachers' content knowledge of biotechnology. The findings showed that the biology teachers in the study had inadequate content knowledge and struggled to understand certain biotechnology concepts and their connections to previously learned topics like genetics, evolution, and reproduction. This highlights the need for in-service teacher education to address these gaps and improve biotechnology instruction.

CONCLUSION

This research study aimed to investigate biology teachers' content knowledge of biotechnology concepts. Specifically, it examined the teachers' understanding of the content associated with biotechnology and identified differences in their knowledge levels based on the test and observed lessons. Employing a qualitative research approach within an interpretive paradigm, this study utilized multiple case study methods to gather and analyse data.

The findings indicate a pressing need for improvements in teacher training programs. It is essential that pre-service training includes biotechnology as a core topic and that in-service teacher education specifically addresses the content of biotechnology for all biology teachers. Many teachers demonstrated challenges in effectively conveying biotechnology concepts, which they often found abstract. Additionally, further research is warranted to explore how biotechnology is interpreted in curricula and textbooks, as well as its overall impact on teaching and learning outcomes.

REFERENCES

Aydemir, M. (2014). *The investigation of pedagogical content knowledge of teachers: The case of teaching Genetics.* A thesis submitted to the Graduate School of Social Sciences of Middle East Technical University. The Department of Elementary Education.

Bailey, C.A. (2007). *A guide to qualitative field research.* (2nd Ed.) Thousand Oaks: Pine Forge Press.

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

Ball, D., Thames, M.H. & Phelps, G. (2008) Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59 (5), 389–407.

Baris C. C. & Kirbaslar, F. G. (2015). A study of certain biology and biotechnology concepts in secondary school and high school coursebooks in terms of scientific competency. *Procedia Social and Behavioral Sciences 174* (2) 420 – 426.

Borgerding, L. A., Sadler, T. D., & Koroly, M. J. (2013). Teachers' Concerns about Biotechnology Education. *Journal of Science Education and Technology*, *22* (2), 133–147.

Bruns, J., Gasteiger, H., & Strahl, C. (2021). Conceptualising and measuring domain-specific content knowledge of early childhood educators: A systematic review. *An International Journal of Major Studies in Education* 9 (2), 500 - 538

Chamba, M. (2009). An investigation of the availability and value of in-service education and training for secondary school physical science teachers in Malawi: The case of Blantyre city. *A dissertation submitted in partial fulfilment of the requirements for the Master of Education in Education Administration, Planning and Social Policy*. University of Cape Town, South Africa.

Chimocha S., & Lungu, S.B. (2017). *Achievers Senior Secondary Biology. Student's Book 4.* East African Educational Publishers Ltd. Kenya

Creswell, J.W. (2012). *Educational research: Planning, Conducting and evaluating quantitative and qualitative research* (4th Ed.). Boston, MA: Pearson

Creswell, J.W. (2014). *Research Design. Qualitative, quantitative & mixed methods approaches* (4th Ed) Sage Publications, Inc. California. U.S.A.

Department of Teacher Education and Development (2018). SMASSE Inset Malawi. Biotechnology. A paper presented at SMASSE National INSET, Lilongwe

Hill, K. M & Luft J.A. (2015). Exploring beginning teachers' content knowledge. J. A. Luft & S. L. Dubois (Eds.), *Newly Hired Teachers of Science*, 57–74. Sense Publishers.

Juttner, M., Boone, W., Park, S., & Neuhaus, B.J. (2013). Development and use of a test instrument to measure biology teachers' content knowledge (CK) and pedagogical content knowledge (PCK). *Education, Assessment, Evaluation and Accountability*, 25 (1), 45 – 67. Doi:10.1007/s11092-013-9157-y

Kapyla, M., Heikkenen, J., & Asunta, T. (2009). The influence of content knowledge on pedagogical content knowledge a case of teaching photosynthesis and plant growth. *International Journal of Science Education*, *31*(10), 1395-1415.

Kidman, G. (2009). Attitudes and Interests Towards Biotechnology: The Mismatch Between Students and Teachers. *Eurasia Journal of Mathematics*, *5*(2), 135–143.

Kind, V. (2014). Science teachers' content knowledge. Exploring mathematics and science teachers' knowledge (Editors: Venkat, H., Rollnick, M., Loughran, J., and Askew, M.,) Abingdon: Routledge. Chapter 2 pp 15 – 29.

Kivunja, C & Kuyini, A.B. (2017). Understanding and applying research Paradigms in an educational context. *International Journal of Higher Education* 6(5) 26 – 41 http://doi.org/10.5430/ijhe.v6n5p26

Maniraho, J.F. (2017). The pedagogical content knowledge (PCK) of Rwandan grade six mathematics teachers and its relationship to student learning Unpublished PhD Thesis. School of Education, College of Humanities, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

McConnell, T.J., Parker, J.M., Eberhardt, J. (2013). Assessing teachers' science content knowledge: a strategy for assessing depth of understanding. *Journal of Science Teacher Education.* 24, 717 – 743. Doi:10.1007/s10972-013-9342-3

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

Ministry of Education (2018). Biotechnology. SMASSE National INSET. Department of Teacher Education and Development. Lilongwe. Malawi.

Ministry of Education, Science and Technology (2013). *Syllabus for Biology. Forms 3 and 4.* Malawi Institute of Education, Domasi. Malawi.

Moreland J., Jones, A., and Cowei B. (2006). Developing pedagogical content knowledge for the new sciences: The example of biotechnology. *Teaching Education. 17* (2), 143 – 155.

Mphathiwa, L (2015). *An investigation into the topic specific pedagogical content knowledge of Botswana social studies teachers: The case of 'water resources and their management'*. A PhD thesis. University of the Witwatersrand. Johannesburg.

Mthethwa-Kunene, E., Onwu G. O. & De Villiers, R. (2015). Exploring biology teachers' pedagogical content knowledge in the teaching of genetics in Swaziland science classrooms. *International Journal of Science Education*. 37 (7), 1140 – 1165

Naz, Z. (2015). Introduction to biotechnology. Research Gate. https://www.researchgate.net/publication/284169166

Njolinjo, B. W. (2014). *Arise with Biology Students' Book 4.* CLAIM Ltd. Blantyre. Malawi

O'Brien, S. (2017). *Topic specific pedagogical content knowledge (TSPCK) in redox and electrochemistry of Experienced teachers*. A published PhD Dissertation. Stony Brook University. ProQuest LLC. 789 East Eisenhower Parkway. USA.

Özden, M., (2008). The effect of content knowledge on pedagogical content knowledge: The case of teaching phases of matters. *Educational Sciences: Theory and Practice,* 8(2), 633-645.

Ramli, M., Karyanto, P., & Wulandari, S. (2019). How do you teach? Teachers' perceptions on teaching biology and pedagogical content knowledge and skills. The 2nd International Conference on Science, Mathematics, Environment, and Education. AIP Conference Proceedings 2194, 020100 – 1 – 020100 – 7. http://doi.org/10.1063/1.5139832

Sakala, J. (2013). Factors contributing to excess use of the lecture method of teaching among high school teachers in selected schools of Kitwe and Kalulushi districts: lessons for educational administrators. *A published Master of Education in Educational Administration of the University of Zambia*. University of Zambia.

Schmelzing S., Van Driel, J.H., Jüttner, M., Brandenbusch, S., Sandmann, A. & Neuhaus, B.J. (2013) Development, evaluation, and validation of a paper-and-pencil test for measuring two components of biology teachers' pedagogical content knowledge concerning the "cardiovascular system" *International Journal of Science and Mathematics Education* 11: 1369 -1390.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Research, 15*(2), 4-14.

Shulman, L.S. (1987). Knowledge and teaching: foundations of a new reform. *Harvard Educational Review, 57* (1), 1 – 22.

Srutirupa P. & Mohalik R. (2013). A modern approach to train bioscience teachers in biotechnology at the secondary level. *An international, refereed journal in education*. *2* (1), 1-13

Wilson, C.D.; Stuhlsatz, M; Hvidsten, C. & Gardner, A. (2018). Analysis of practice and teacher PCK: Inferences from professional development research. S. Uzzo, S. Graves, E. Shay, M. Harford & R. Thompson (Eds). *Pedagogical content knowledge in STEM. Research to practice*. College Station, Texas, USA.

Zaare M. (2013). An investigation into the effect of classroom observation on teaching methodology. *Procedia – Social and Behavioral Sciences* 70 605 – 614.

Zhao, D. & Fan, L. (2020). What is the Most Important Source for Teachers' Knowledge

Article DOI: https://doi.org/10.37284/eajes.8.1.2774

Development? A Meta-Analysis of 27 Empirical Studies on the Sources of Teachers' Knowledge. *Best Evidence in Chinese Education, 10(2):*1375 – 1393.

