



Perceptions of Pre-service teachers in Teaching Genetics through PlayPosit in a Technology-Enabled Learning Environment in one University in South Africa

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ABSTRACT

Most South African pre-service seemingly consider teaching genetics as challenging from both a conceptual and language standpoint. Teachers and students still see the teaching and learning of genetics as challenging despite regulations by CAPS requiring teachers to use textbooks and other ICT-related resources. This is because the examination guidelines are silent on how to provide resources to teach genetics. A qualitative study was used to explore pre-service teachers' experiences teaching genetics concepts in a technology-enabled learning environment (TELE) at one university in South Africa using PlayPosit. The study investigated how pre-service teachers use technical, pedagogical, and content knowledge to improve students' conceptual comprehension. It is guided by the technical Pedagogical Content Knowledge (TPACK) framework. Five randomly chosen Level 4 Science Education pre-service teachers participated in open-ended interviews and active classroom observation to gather data. A structured TPACK-aligned protocol was used to gather observation data during genetics classes taught by pre-service teachers. A summary of teaching competency across TPACK categories was provided after field notes on instructional strategies and technology integration were qualitatively coded to find trends. Five major themes emerged from the thematic analysis: how modules are delivered, who owns ICT devices, ICTs are used in the classroom, TELE experiences, and opinions on the value of technology in genetics education. The results demonstrate that pre-service teachers were generally able to use PlayPosit to teach genetics while integrating technology, pedagogy, and subject. Technology encouraged students' engagement, critical thinking, and comprehension of genetics concepts while supporting interactive, learner-centred learning. However, several barriers were noted, including the need for reliable electricity and internet access, time constraints, and a lack of technical expertise. To improve the efficient use of digital technologies in Life Sciences instruction, the study suggests strengthening teacher training in technology integration and ensuring reliable technological infrastructure and support.

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INTRODUCTION

Genetics education is a cornerstone of Life Sciences curricula globally, including in South Africa, where the Life Sciences Curriculum and Assessment Policy Statement (CAPS) emphasises understanding of genes, heredity, and evolutionary processes (DBE, 2011). Despite its importance, genetics is widely recognised as conceptually difficult, posing challenges for both teachers and learners (Focant, Rezsöhazy & De Kesel, 2025; Osei, 2022). Traditional teacher-centred approaches often emphasise rote memorisation over conceptual understanding, limiting learners' ability to apply knowledge in authentic contexts (Cooke et al., 2021; Alessa & Hussein, 2023).

Simultaneously, the Fourth Industrial Revolution has changed expectations for science education, emphasising the necessity of technology-enhanced learning environments (TELE) that promote individualised, interactive, and active learning (Kyza, 2023; Valtonen et al., 2021). According to the Technological Pedagogical Subject Knowledge (TPACK) framework, teachers must strike a balance between technological proficiency, pedagogical techniques, and subject mastery to integrate technology meaningfully (Mishra & Koehler, 2006; Koehler et al., 2013).

Pre-service teachers' acquaintance with digital resources and their capacity to use them pedagogically, however, continue to differ, according to research (Uerz et al., 2018; Graziano et al., 2023). Technology is introduced superficially in many teacher-education programs, emphasising availability over strategic usage to improve learning outcomes. Because of this, learners' engagement and conceptual understanding may be restricted even in the presence of digital infrastructure (Riivari et al., 2021).

LITERATURE REVIEW

Technology integration in science education is becoming more widely acknowledged as a key factor in raising student interest, comprehension, and critical thinking. Teachers can communicate difficult subjects in more approachable ways by mixing visual, audio, and interactive elements using digital resources like learning management systems, interactive movies, and virtual simulations (Lu & Hanim, 2024). This implies that technology in the life sciences, especially genetics, enables learners to visualise abstract concepts that are challenging to understand through traditional lecture methods alone, such as allele inheritance, gene expression, and chromosomal activity.

PlayPosit is a digital platform that uses polls, questions, and reflective prompts to turn passive video content into interactive educational experiences (Rezaei, 2024). It is further argued that the application of PlayPosit in science education promotes higher order thinking as well as subject comprehension (Gastineau-Stevens, 2023). Pre-service teachers can pause and clarify ideas, dispel misunderstandings, and encourage learner contemplation with interactive videos. According to research, pre-service teachers can design learner-centred sessions by combining multimedia resources with pedagogical practices using PlayPosit (Addo, 2024). In other words, this platform improves learners' conceptual understanding and engagement by facilitating scaffolding, instant feedback, and formative assessment throughout the class.

Pedagogical approaches that actively involve learners in creating understanding are necessary for effective genetics instruction. Peer learning and critical thinking are encouraged by methods including problem-solving exercises, student-led demonstrations, and class discussions (Haripottawekul & Wang, 2025). Pre-service teachers can use technology for interactive learning by incorporating these tactics into PlayPosit classes, which enable learners to apply concepts, think critically, and solve real-world problems. It has been demonstrated that pedagogical strategies that combine digital resources with active learning enhance motivation among learners, retention, and conceptual clarity (Mushtaq & Iqbal, 2024).

The interaction of content knowledge (CK), pedagogical knowledge (PK), and technical knowledge (TK) in successful instruction is highlighted by the TPACK framework (Koehler, Mishra, & Cain, 2013). Robust TPACK enables pre-service teachers to effectively incorporate technology to improve content delivery and promote active

learning (Zhang, et. al., 2025). Thus, TPACK-informed methods in genetics include choosing relevant videos, pausing for clarity, illustrating inheritance patterns with diagrams, and encouraging learner explanations. It can then be argued that pre-service teachers with emerging TPACK are better able to create courses that balance instructional strategies, digital technologies, and content objectives, leading to higher learning results.

The TPACK approach emphasises how content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) interact in effective education (Koehler, Mishra, & Cain, 2013). Pre-service teachers can use technology to enhance material delivery and encourage active learning with the help of robust TPACK. In genetics, TPACK-informed strategies include selecting pertinent videos, pausing for clarification, utilising diagrams to show inheritance patterns, and supporting student explanations. The implication of the preceding arguments is that pre-service teachers with emerging TPACK are better able to design courses that balance digital tools, instructional methodologies, and subject objectives, resulting in superior learning outcomes.

Engagement and retention are strongly influenced using multimedia and interactive tools. PlayPosit supports learner engagement by combining visual representations, audio explanations, and interactive prompts, which can capture learners' attention and maintain interest throughout the lesson (Gastineau-Stevens, 2023). Hence it could be argued that when learners actively participate, answering questions, discussing with peers, and interacting with content, they are more likely to retain knowledge. The preceding views highlight that the lessons integrating video-based interactive learning and active participation enhance both short-term comprehension and long-term retention, especially in topics involving abstract concepts like genetics.

To guarantee that technology integration satisfies educational standards and learning objectives, curriculum alignment is essential. The Life Sciences Curriculum Guidelines (CAPS) place an immense value on the development of critical thinking, practical skills, and conceptual understanding (DoE, 2011). It is expected that pre-service teachers can use PlayPosit to create lessons that support learner-centred approaches, incorporate assessment questions, and follow curricular standards. According to research, teachers can effectively scaffold courses to facilitate concept mastery and learners are more likely to attain intended learning outcomes when instructional resources are linked with curriculum goals (Sari, Mahanal & Setiawan, 2024).

In this study, the researchers observed that pre-service teachers face difficulties when integrating technology, despite its advantages. Research echoes these sentiments in that time constraints, a lack of technical expertise, a lack of knowledge with platform features, and infrastructural constraints like erratic network connectivity or electricity are common problems (Pons, et. al., 2023). Thus, these difficulties may limit opportunities for active learning and make it more difficult to use interactive technologies effectively. Hence, to enhance technological proficiency, pedagogical integration, and TPACK competencies and enable pre-service teachers to fully use the educational potential of resources such as PlayPosit, reliable infrastructure, technical support, focused professional development, and practical training are crucial.

Although earlier research highlights the advantages of interactive movies and technology-enhanced learning, little is known about how pre-service teachers particularly incorporate PlayPosit into the teaching of difficult Life Sciences subjects like genetics. Most of the current research ignores pre-service teachers' complex experiences, pedagogical choices, and TPACK-informed practices in favour of concentrating on general technology adoption or learner achievement results. Additionally, there is little evidence on the interplay between technology use, curriculum alignment, and the development of critical thinking and problem-solving skills in a classroom context. up order to fill up these gaps, this study investigates how pre-service teachers use PlayPosit, how they integrate pedagogy and content knowledge, and how this affects interactive, learner-centred instruction.

Drawing from the published literature examined in this work, technology-enhanced platforms can make science education more interactive, learner-centred, and conceptually rich when combined with pedagogical techniques and topic understanding. A tool that encourages critical thinking, active participation, and curriculum-aligned genetics

instruction is PlayPosit. However, institutional support, continuous professional development, and teacher readiness are necessary for successful implementation. Building on these findings, the current study examines how pre-service teachers use PlayPosit to combine technology, pedagogy, and content. It highlights the gaps in TPACK application, difficulties encountered, and methods for successful classroom deployment.

THEORETICAL FRAMEWORK

The Technological, Pedagogical, and Content Knowledge (TPACK) (Koehler, Mishra & Cain, 2013) served as the foundation for this study, which examined the pre-service teachers' perceptions of teaching and learning genetics through a technology-enabled learning environment. Additionally, the study's pre-service teachers received training and were permitted to engage in peer microteaching. For them to be able to purposefully incorporate technology into science education, they must be able to acquire and connect technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) to form technological pedagogical content knowledge (TPACK) (Koehler et al., 2014). As a result, Figure 1 below shows the seven elements that were utilised to link this research with PlayPosit (ICT) and the study's analyses.

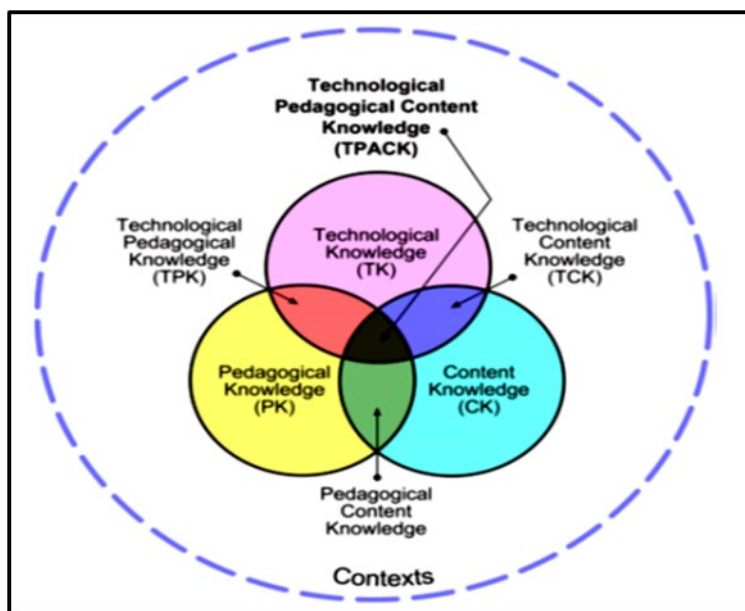


Fig. 1. The TPACK Framework and Its Knowledge Component

The framework consists of three primary knowledge domains:

Content Knowledge (CK): comprehending the material being taught. Pre-service teachers' understanding of genetic concepts, including alleles, genotypes, phenotypes, and inheritance patterns, is referred to in this study as CK. Based on observations, pre-teachers would be expected to demonstrate that they were able to effectively scaffold learners to understand, resolve misconceptions, and provide clear explanations of ideas.

Pedagogical Knowledge (PK): recognising instructional techniques and approaches that promote learning. Learner-centred strategies, problem-solving exercises, group discussions, and the application of active learning approaches are all part of PK in this context. According to the study, pre-service teachers should demonstrate great pedagogical application by pausing PlayPosit videos to engage learners, asking them to demonstrate understanding, and making connections between new material and past knowledge.

Technological Knowledge (TK): having the ability to effectively use technology. TK refers to pre-service teachers' proficiency with PlayPosit, interactive boards, projectors, Moodle, and other digital platforms. The purpose of this study is to ascertain the various pre-service teachers' levels of technological proficiency regarding their ability to incorporate interactive questions into PlayPosit. It will also identify those who encountered difficulties and had to rely on passive video playback due to unfamiliarity or technical issues. The strength of the TPACK framework lies in its focus on the intersections of these knowledge domains:

Pedagogical Content Knowledge (PCK): In this study, the researchers will investigate how pre-service teachers improve learners' comprehension of difficult genetics concepts by using questions, diagrams, and scaffolding techniques.

Technological Content Knowledge (TCK): How content can be represented and made clearer by technology. Using PlayPosit videos, learners should be able to visualise allele interactions and inheritance patterns, which help them to comprehend concepts.

Technological Pedagogical Knowledge (TPK): How instructional strategies can be aided by technology. To show that they understand how technology improves pedagogy, pre-service teachers should be able to incorporate interactive video prompts to promote conversation and problem-solving.

Technological Pedagogical Content Knowledge (TPACK): the complete fusion of subject matter, pedagogy, and technology. To encourage critical thinking and active learning, effective lessons should pause videos, ask learners to answer problems at the board, and combine conversations with visual aids. Pre-service teachers are expected to show that they can successfully incorporate TPACK in a creative, self-assured, and technologically proficient manner.

The TPACK framework guided both the data collection and the analysis of this study by providing a structured way to examine how technology, pedagogy, and content knowledge interact in teaching. During data collection, classroom observations were carefully designed to focus on how pre-service teachers used PlayPosit to teach genetics. The observations paid attention not only to the accuracy of the genetic content but also to the teaching strategies applied and the ways in which technology supported learning. In addition, post lesson interviews were conducted to explore participants' perceptions of their teaching approaches. These interviews helped reveal how the teachers understood the relationship between content knowledge, pedagogical knowledge, and technological knowledge, including areas where these domains supported each other or created challenges.

For the analysis, thematic coding was used to identify patterns in the data and link them to specific TPACK components. For example, instances where PlayPosit was used to make complex genetic concepts easier to understand were associated with technological content knowledge. Situations where teachers paused videos to encourage discussion and problem solving reflected technological pedagogical knowledge. More comprehensive practices, such as designing activities that combined content, pedagogy, and technology in a meaningful way, were linked to the full TPACK framework. This approach allowed the researchers to systematically interpret how different forms of knowledge were applied in practice.

The TPACK framework was particularly suitable for this study because it captures the complexity of modern teaching, especially in subjects like genetics that require clear explanations and engaging instructional methods. It also aligns closely with the objectives of the study, which aimed to understand how pre-service teachers use PlayPosit to teach genetics, promote critical thinking, and meet curriculum requirements. Furthermore, the framework helps identify areas where teachers may need additional support. By highlighting gaps in the integration of technology, pedagogy, and content, the study can inform the design of targeted professional development programmes.

Overall, using TPACK as a theoretical framework enabled a comprehensive investigation of how pre-service teachers integrate different forms of knowledge when teaching genetics with PlayPosit. The findings were expected

to show how the intersection of these knowledge domains supports curriculum aligned teaching, learner centred engagement, and the development of critical thinking skills. In addition, the framework provides insight into challenges such as limited confidence or technological skills, which can guide future improvements in teacher training and instructional support.

OBJECTIVES OF THE STUDY

The study is guided by four interrelated objectives that collectively examine the pedagogical value and practical implementation of PlayPosit in the teaching of Grade 12 Life Sciences, with a specific focus on genetics. Firstly, the study seeks to examine the extent to which the use of PlayPosit aligns with the prescribed curriculum requirements and supports effective teaching and learning of complex genetics concepts. This involves evaluating how the platform's interactive features can be used to present content in ways that are consistent with curriculum goals while enhancing conceptual clarity and learner understanding.

Secondly, the study investigates how pre-service teachers integrate technological, pedagogical, and content knowledge when using PlayPosit, drawing on the Technological Pedagogical Content Knowledge (TPACK) framework. This objective focuses on understanding how teachers combine their subject knowledge of genetics, their pedagogical strategies, and their use of digital tools to create meaningful and effective learning experiences.

Thirdly, the study explores how the use of PlayPosit influences pre-service teachers' instructional practices and contributes to student learning outcomes. It examines the extent to which the platform promotes learner engagement, supports the development of critical thinking skills, and facilitates deeper conceptual understanding of genetics topics, which are often perceived as abstract and challenging.

Finally, the study aims to identify the challenges that pre-service teachers encounter when implementing PlayPosit in their teaching, as well as to examine the role of institutional support in this process. This includes consideration of factors such as access to technological resources, infrastructure, and technical assistance, and how these elements enable or constrain the effective integration of digital tools in the classroom. Together, these objectives provide a comprehensive framework for understanding both the opportunities and limitations associated with the use of PlayPosit in Life Sciences education.

RESEARCH METHODS

To investigate pre-service teachers' experiences and methods regarding the use of PlayPosit in teaching Grade 12 Life Sciences (genetics), this study used a qualitative, interpretive research approach. In line with the TPACK framework, a qualitative approach made it possible to gather extensive, contextualised data on learner engagement, technology integration, and instructional techniques (Jibril & Adedokun-Shittu, 2024). To improve data triangulation and offer complementary viewpoints, the study integrated semi-structured interviews and observations, guaranteeing the reliability of the results (Chand, 2025).

Instead of only assessing performance outcomes, the interpretive design focused on understanding "how and why" pre-service teachers combined technology, pedagogy, and subject matter knowledge. In line with study goals to investigate the balance or conflict between PlayPosit use, curriculum requirements, and learner comprehension, it made it possible to investigate both individual teaching techniques and institutional influences.

Population and Sample

All 74 pre-service teachers enrolled in the institution's Life Sciences teaching program who had access to PlayPosit, and the necessary digital infrastructure made up the target group. Only five participants were chosen for in-depth analysis due to the study's qualitative style and the significant time needed for observations and interviews. Participants had to be enrolled in the program, have taken part in Grade 12 genetics-related PlayPosit-supported learning activities, and provide their agreement to participate in the study in order to meet the inclusion criteria. Pre-service teachers who did not give their assent or who did not fully engage in the PlayPosit activities were not included. Following the application of these criteria, five eligible participants were chosen at random and given numbers. To maintain their anonymity, these volunteers were assigned codes PST1–PST5. This random selection helped reduce sampling bias while also ensuring that the participants were reasonably representative of the wider group in terms of prior exposure to PlayPosit, subject knowledge, and technological proficiency (Ahmad, Alias & Razak, 2023). The inclusion criteria for these participants were that they had experience using PlayPosit to deliver genetics lessons, were available during the data collection period, and were willing to participate in follow-up interviews and observations. To uphold ethical standards and maintain confidentiality, pseudonyms (PST1–PST5) were used.

Data Collection Instruments

Each participant was observed during a single 30-minute lesson in which PlayPosit was used to teach a Grade 12 genetics topic. The lesson centred on Mendelian inheritance and genetic crosses, specifically exploring monohybrid crosses, dominant and recessive inheritance patterns, genotype and phenotype ratios, and the application of Punnett squares to predict the inheritance of traits. The observations were undertaken to investigate how pre-service teachers incorporated PlayPosit into their instructional practices and supported learner engagement and conceptual understanding of genetics. Alignment with the TPACK dimensions, including technological, pedagogical, and content knowledge as well as their integration were also assessed during the lesson observations and interviews. To provide detailed descriptions of classroom practices, field notes were used to capture actions, interactions, and verbatim conversations. Following the lessons, post-lesson interviews were conducted to explore participants' experiences, challenges, and perceptions of using PlayPosit. These interviews examined the integration of technology in teaching genetics, the development of students' critical thinking and understanding of genetic concepts, alignment with the Life Sciences curriculum (CAPS), and the nature of institutional support and constraints. All interviews were audio-recorded, transcribed verbatim, and anonymised.

Data Analysis and Quality Assurance

To obtain a comprehensive understanding of instructional strategies, technology integration, and learner responses, all observation notes and interview transcripts were reviewed multiple times (Lofland et al., 2022). The data were then open-coded to identify emerging patterns aligned with the TPACK framework, including instances of technological-content knowledge, pedagogical knowledge, and technological-pedagogical knowledge. These initial codes were subsequently grouped into broader categories reflecting content knowledge (CK), technological knowledge (TK), pedagogical knowledge (PK), and their integrated TPACK dimensions. In line with Flick's (2022) principles, themes were identified and refined, focusing on the application of technology within an institutional context, the development of genetic concepts through instruction, the enhancement of critical thinking and problem-solving skills, experiences and challenges associated with PlayPosit, and learner engagement in relation to curriculum alignment.

These themes were supported by verbatim quotations drawn from both classroom observations and interview data. The analysis further examined how and why teaching practices reflected the integration of content, pedagogy, and technology, with particular attention to variations in technological proficiency, pedagogical approaches, and levels of learner engagement, ultimately highlighting effective TPACK practices and areas for professional development.

To ensure quality and trustworthiness, the study adhered to Adler’s (2022) criteria, including triangulation through the comparison of observation data with field notes and interview responses, peer debriefing to minimise researcher bias in coding and thematic interpretation, the use of thick description to provide detailed and contextualised accounts of classroom interactions and learner responses, and member checking, whereby participants reviewed summaries of the findings to validate the interpretations.

Limitations, Delimitations and Ethical considerations

The study was delimited to pre-service teachers teaching Grade 12 genetics using PlayPosit, with only five of the 74 participants purposefully selected for observation and interviews. Rather than quantitatively assessing learning outcomes, the analysis concentrated on instructional processes and participants’ experiences. However, the small sample size limits the generalisability of the findings to the broader population of pre-service teachers, and differences in institutional support and technological infrastructure may affect replicability. In addition, the observer effect may have influenced participants’ behaviour, as teachers could alter their practices when aware of being observed, and time constraints meant that only one lesson per participant was observed. Ethical considerations were guided by Knight (2023), with all participants providing informed consent and pseudonyms (PST1–PST5) used to protect their identities. Participants were informed of their right to withdraw at any time, and all data were securely stored and used solely for research purposes. Institutional approval was obtained prior to data collection.

RESULTS AND DISCUSSION

Observation results

With an emphasis on how pre-service teachers applied their knowledge, abilities, and strategies in actual classroom settings, the lesson observation data were examined as qualitative proof of teaching techniques. This organised protocol in line with the TPACK framework guided observations, although analysis placed more emphasis on descriptive and interpretive comprehension than just numerical score. A qualitative description of the pre-service teachers' observed teaching methods during genetics lessons using PlayPosit is given in Table 1, which shows the results across all teaching knowledge dimensions (N=5). It shows how participants combined pedagogy, technology, and subject-matter expertise, emphasising interactive techniques, student involvement, and the use of additional teaching tools. The table shows differences in instructional strategies, highlighting both successful methods and areas that might require more assistance or training.

Table 1. Pre-service teachers’ competence in teaching genetics with PlayPosit

Dimension of teaching knowledge	Observation results
Subject matter knowledge	4 proficient, 1 needs improvement
Technological knowledge	3 proficient, 2 needs improvement
Pedagogical knowledge	4 proficient, 1 needs improvement
Tech-pedagogical knowledge	3 proficient, 2 needs improvement
Tech-content knowledge	3 proficient, 2 needs improvement
Pedagogical content knowledge	3 proficient, 2 needs improvement
TPACK (tech-pedagogical-content)	3 proficient, 2 needs improvement

To fully comprehend the teaching methods of the participants, all observation notes and field data were examined several times. PlayPosit integration, interactions between learners, teaching behaviours, and the use of supplemental materials were all taken into consideration.

To find emerging patterns in the classroom, observation data was open-coded. Codes indicated activities and procedures pertinent to each TPACK component, such as providing a clear introduction to the subject of genetics, using PlayPosit for interactive questioning, or letting students explain their answers in front of the class. Subject Matter Knowledge, Technological Knowledge, Pedagogical Knowledge, and the integrated TPACK dimensions were the categories into which these codes were further divided to indicate more general domains.

Themes that encapsulated the core of instructional methods surfaced through repeated reading and coding (Lofland, et. al., 2022). Learner-centred engagement, innovative use of visual aids, technology-mediated reflection, and difficulties in integrating technology were some of the themes. Direct observations were used to provide illustrative instances, such as when participants paused movies to talk about genetic crosses or asked students to use visual aids to show that they understood (Addo, 2024).

Instead of only measuring performance, the research focused on how and why participants' teaching actions reflected their knowledge and abilities. Participants' differences, such as differing levels of confidence in their ability to present content or their level of PlayPosit proficiency, were evaluated as signs of developmental needs and possible areas for expert assistance.

Thick description, which offers detailed, contextualised accounts of classroom interactions, and triangulation, which connects observational data with post-lesson participant perspectives, were used to maintain qualitative rigour. To guarantee consistency and reduce bias, observers cross-checked patterns (Ononuju, 2023). The study highlights the complex ways in which pre-service teachers blend technology, pedagogy, and subject knowledge through qualitative analysis of observation data. This method enables a more thorough comprehension of instructional strategies, the interactive and learner-centred learning opportunities that PlayPosit provides (Lu & Hanim, 2024). In addition, the areas that require professional development to improve pedagogical and technological integration can be easily identified (Pons, et. al., 2023).

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Interview results

The semi-structured interviews conducted with the 5 pre-service teachers provided deeper insight into their experiences of integrating PlayPosit in genetics teaching. The study adhered to ethical norms using pseudonyms for the participants (Khan, 2024). Thus, the participants and their interviews were coded as follows: Interview for Pre-service Teacher One (IN PST1), Pre-service Teacher Two (IN PST2), Pre-service Teacher Three (IN PST3), Pre-service Teacher Four (IN PST4), and Pre-service Teacher Five (IN PST5).

The main goal of this study was to methodically examine the data to extract significant insights from the verbatim transcriptions made by pre-service teachers. The data revealed the following themes: Participants' opinions of technological integration, instructional techniques, student involvement, and the growth of critical thinking and

problem-solving abilities in the classroom were all examined in the interviews. Thematic analysis was used to examine the replies to find recurrent themes and significant information pertaining to the study's goals.

Five pre-service teachers were interviewed to gain deep insights into their experiences teaching genetics in Grade 12 Life Sciences using PlayPosit. Six main topics emerged from the thematic analysis, all of which represented the TPACK framework's integration of technology, pedagogy, and content knowledge. Six main themes emerged from the thematic analysis of pre-service teachers' interviews, reflecting their experiences teaching genetics using PlayPosit.

Institutional Environment Regarding Technology Use (TK/TCK): Participants emphasised that in general, their university offered sufficient technology infrastructure, such as projectors, smartboards, Wi-Fi connectivity, and digital platforms like Microsoft Teams and Moodle. Noted in PST1, *“Technology is provided in terms of hardware and software... it is easy to access but not always sustainable,”* while IN PST5 added, *“We use Moodle for assessments, Microsoft Teams for discussions, and PlayPosit to study and teach.”* Pre-service teachers perceived the environment as conducive to technology integration, with technical support readily available (IN PST4) who stated that *“This technological foundation enabled the effective use of PlayPosit in classroom instruction.”* These findings are in line with the assertions that the Fourth Industrial Revolution (4IR) has changed expectations for science education, emphasising the necessity of technology-enhanced learning environments (TELE) that promote individualised, interactive, and active learning (Kyza, 2023; Valtonen et al., 2021).

Genetic Concepts Developed by Teachers (CK/TCK/TPACK): Teachers claimed that PlayPosit helped learners understand genetic concepts like genes, alleles, phenotypes, genotypes, and chromosomal architecture. IN PST1 explained, *“Genotypes and phenotypes... learners understand and differentiate between genotype and phenotype.”* In addition, IN PST3 said *“PlayPosit video-based instruction, combined with traditional teaching methods, allowed teachers to pause and clarify misconceptions.”* IN PST2 emphasized the advantage of dual-mode learning: *“Using slides and videos made me able to explain more... learners could see and hear what I was talking about.”* The pre-service teachers' perceptions are echoed in Mishra & Koehler, (2006) ; Koehler et al., (2013) who argue that the Technological Pedagogical subject Knowledge (TPACK) framework enables teachers to strike a balance between technological proficiency, pedagogical techniques, and subject mastery to integrate technology meaningfully. This integration of content with technology enhanced conceptual understanding and aligned with TPACK principles.

Critical Skills Development (PCK/TPACK): PlayPosit improved learners' critical thinking, reasoning, focus, and problem-solving abilities, according to pre-service teachers. Noted in PST2, *“Skills like analytical reasoning, decision-making, and creativity were developed,”* while IN PST3 highlighted that the students were able to recall prior knowledge and apply it to genetic crosses: *“Students recall previous concepts, summarise, interpret, and apply information to solve genetic crosses.”* The integration of content, pedagogy, and technology provided learners with opportunities to engage actively with genetic concepts and think critically, reflecting a strong TPACK alignment. The pre-service teachers' views refute the argument that despite its importance, genetics is widely recognized as conceptually difficult, posing challenges for both teachers and learners (Focant, et. al., 2025; Osei, 2022).

Experiences Using PlayPosit for Teaching Genetics (TPK/TPACK): Participants found PlayPosit to be well-organised and time-efficient, freeing them up to concentrate on teaching instead of creating diagrams. IN PST4 stated, *“It was easy to use PlayPosit to limit the time I use for drawings and explanations... helps me to be well-organised.”* Teachers also leveraged creative teaching aids, using video and audio to accommodate diverse learning styles (IN PST2): *“With videos, it's creativity in its own... students understand differently; some visually, others via the teacher.”* These strategies illustrate the interplay between pedagogical and technological knowledge to enhance learning outcomes. In addition, research has indicated that pedagogical strategies that combine digital resources with active learning enhance motivation among learners, retention, and conceptual clarity (Mushtaq & Iqbal, 2024).

Challenges Encountered (TK/TPK): Despite the advantages, several participants encountered operational and technological difficulties, such as inadequate knowledge from occasional use (IN PST2) or trouble sharing questions

on PlayPosit (IN PST1): *"I do not normally use it in my presentations... maybe I have limited knowledge about uploading questions."* Time constraints of videos (IN PST5) and potential electricity or network issues (IN PST3) were also noted. Difficulties were such as time demands of video-based activities were emphasised by PST5, who noted that *"The biggest challenge was fitting the video activities into a 30-minute lesson" because the films occasionally cut into the amount of time available for discussion and feedback.*" PST3 cited technical difficulties, stating that *"When the network was slow, the videos took time to load, which interrupted the flow of the lesson."* Another concern that could hinder PlayPosit's successful implementation was the possibility of power outages. Research echoes these sentiments in that time constraints, a lack of technical expertise, a lack of knowledge with platform features, and infrastructural constraints like erratic network connectivity or electricity are common problems (Pons, et. al., 2023). These findings suggest that targeted training in PlayPosit could strengthen teachers' TPK and overall TPACK competencies.

PlayPosit and Curriculum Alignment (TPK/TPACK/PCK): PlayPosit was consistently evaluated by participants as being in line with the requirements of the CAPS curriculum and useful for encouraging critical thinking, creativity, and learner engagement (DoE, 2011). According to PST2, *"PlayPosit helps teachers make lessons more creative and effective for learners,"* while IN PST3 noted, *"PlayPosit relates to curriculum demands... students develop critical thinking skills such as creativity."* Additionally, pre-service teachers noted improved focus and retention of information. Participants reported that PlayPosit supported learner engagement, skill development, and active participation. PST1 observed that *"PlayPosit keeps learners interested in the lesson because they are constantly interacting with the video and answering questions. It helps them stay focused from the beginning to the end of the lesson"*. Regarding skill development, PST5 explained that *"PlayPosit helps learners develop different skills, such as critical thinking and problem-solving, because they have to think carefully about the questions and apply what they have learned from the video"*. Similarly, PST4 emphasised the learner-centred nature of the platform, stating that *"PlayPosit promotes learner-centred methods because learners are actively involved in the lesson instead of just listening to the teacher. Students remember what they watch and learn because they participate throughout the lesson"*. These experiences demonstrate how TPACK-informed teaching using PlayPosit supports curriculum-aligned, interactive, and student-centred learning. Research supports these findings in that PlayPosit supports learner engagement by combining visual representations, audio explanations, and interactive prompts, which can capture learners' attention and maintain interest throughout the lesson (Gastineau-Stevens, 2023). Gastineau-Stevens (2023).

The findings indicate that PlayPosit enables pre-service teachers to integrate content knowledge, pedagogy, and technology effectively, promoting understanding of genetic concepts, critical thinking, and learner engagement. While the majority exhibited strong TPACK-informed practices, minor challenges, such as limited technical skills, video time constraints, and infrastructure dependencies, highlight areas for further professional development. The results underscore the potential of PlayPosit to transform Life Sciences teaching by fostering active, creative, and reflective learning environments.

CONCLUSION AND RECOMMENDATION

Key insights on pre-service teachers' usage of PlayPosit in teaching Grade 12 Life Sciences genetics were uncovered through the qualitative analysis of classroom observations and post-lesson interviews. Through the integration of PlayPosit videos with visual aids, interactive questioning, and learner explanations, participants displayed growing Technological Pedagogical Content Knowledge (TPACK). Most lessons were learner-centred and helped learners grasp difficult genetic concepts, such as inheritance patterns, genotypes, and phenotypes. PlayPosit functioned as a framework to organise explanations and lead learners through difficult material while promoting critical thinking and problem-solving skills. Teachers' levels of technological competence, however, differed. While most participants felt at ease utilising PlayPosit and other digital tools like Moodle, Microsoft Teams, and smartboards, some found it challenging to upload questions or efficiently manage video time.

These variations demonstrate the necessity of further professional development to improve technological proficiency and self-assurance when using digital platforms. To encourage participation and engagement, most pre-service teachers used learner-centred pedagogical techniques like peer discussion, demonstrations, and reflective

questioning. However, in numerous classes, pre-service teachers mostly focused on playing videos with little interaction, which hindered the chances for higher-order thinking and deeper involvement. This implies that to maximise learning results, effective scaffolding that purposefully blends material, pedagogy, and technology is required. Technology integration was also impacted by the institutional setting.

Participants underlined that efficient PlayPosit use was made possible by dependable internet connectivity, access to digital tools, and technical support. Lessons were more participatory and interesting when these resources were provided. The usage of PlayPosit was in line with CAPS curriculum standards and facilitated interactive instruction that promoted focus, retention of information, and the application of past knowledge to novel genetic issues. However, obstacles, including technical issues, a lack of experience with the platform, schedule restraints, and sporadic power or network outages, prevented it from reaching its full potential. Technology integration in life sciences classrooms should be strengthened by addressing these obstacles through planning, training, and better infrastructure.

Based on the conclusions above, to improve pre-service teachers' efficient use of PlayPosit in genetics instruction, the following suggestions are put forth:

Specific Professional Growth: To improve TPACK integration and develop technological competency (TK/TPK), offer organised training on PlayPosit capabilities, question embedding, and time management.

Support for Instructional Planning: To maximise pedagogical and content integration, encourage pre-service teachers to create lesson plans that purposefully incorporate video content with interactive questions, visual aids, and peer-led explanations.

Peer Observation and Collaborative Learning: Organise peer observation sessions where teachers can demonstrate and exchange best practices for using PlayPosit, promoting the cooperative creation of learner-centred techniques.

Infrastructure and Technical Support: To reduce interruptions during classes, guarantee constant access to dependable network connectivity, energy, and technical support. ICT support should be continuously provided by institutions with a focus on classroom integration.

Curriculum-Aligned Resources: To facilitate lesson planning and encourage active learning, create a library of PlayPosit videos and related educational resources that are in line with the CAPS curriculum.

Mechanisms for introspection and feedback: To determine successful strategies and areas in need of development, pre-service teachers should be encouraged to consider their teaching experiences and get input from learners. Reflection improves TPACK refinement and educational decision-making.

Integration of Higher-Order Thinking Activities: To help pre-service teachers strengthen their critical thinking abilities during PlayPosit lessons, assist them in creating activities that go beyond memory by including tasks such as problem-solving, analysis, and synthesis.

PlayPosit offers a strong platform for teaching genetics that encourages involvement among learners, conceptual comprehension, and critical thinking when properly integrated. To maximise these results and promote creative, interactive Life Sciences education, pre-service teachers' TPACK should be strengthened through professional development, planning assistance, and reflective practice.

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