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Investigating opportunities for integrating methodology when teaching a life science topic (meiosis) to fourth-year pre-service teachers: A case study

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Abstract

Pre-service teachers (PSTs) are expected to effectively integrate their content knowledge with their knowledge of teaching when teaching classes after qualification. This integration can, however, be challenging for PSTs because the two components are often taught separately at teacher education institutions. This qualitative case study investigated the possibilities of integrating the teaching of the two components at a South African university educating future science teachers. Data in the form of video-recorded lectures, video-stimulated recall interviews with a teacher educator, and focus group interviews with 15 PSTs were collected. Data analysis was mainly deductive informed by the topic-specific pedagogical content knowledge conceptual framework. Many opportunities for integrating methodology were created by the teacher educator while teaching meiosis content. The study concludes that integrating methodology when teaching content courses is possible. However, the integration should include explicit discussion of the pedagogical reasoning behind the visible teaching routines.

Keywords: teacher education programmes, pre-service teachers, pedagogical content knowledge, topic-specific pedagogical content knowledge, meiosis, subject matter representations, curricular saliency, pedagogical reasoning

Introduction

Teacher education has a dual purpose: teaching content or making sure pre-service teachers (PSTs) learn content (the disciplinary component), and teaching PSTs how to teach that content—the professional component (Garbett, 2012). However, the two main models of teacher education programme that are used in higher education institutions—the concurrent model and the consecutive model (Sederevičiūtė-Pačiauskienė & Vainorytė, 2015)—teach these two components separately. At many universities, in the concurrent model, PSTs learn the disciplinary studies alongside the pedagogical studies but in separate programmes (Zuzovsky & Donitsa-Schmidt, 2017). In the consecutive model, the PSTs first obtain an academic degree in the discipline that is related to the subjects that they will teach at schools (Sederevičiūtė-Pačiauskienė & Vainorytė, 2015). Thereafter they complete a teaching qualification where the pedagogical knowledge needed to teach that particular subject is taught, usually a post-graduate certificate in education (Murray, 2005).

Despite the fact that the two components are taught separately, there is still an expectation that the teacher, after qualification, would be able to automatically integrate these two components for effective teaching to occur. Experience of supervising teaching experience practicals—what Rusznyak and Bertram (2021) referred to as work integrated learning (WIL)—has shown that integrating the two components during teaching is a challenge for PSTs because they are taught as separate courses at teacher education institutions. Garbett (2012) argued that it should be the role of a teacher educator to marry the teaching of content and how to teach it during the teaching of PSTs. That was the motivation for this study in which we investigated the opportunities for integrating methodology[1] when teaching a content course to PSTs.

Nyamupangedengu and Lelliott (2018) argued that there needs to be integration between the teaching and learning of content and methodology for PSTs to gain pedagogical content knowledge (PCK)—knowledge of how to teach. This PCK would enable them to enter the classroom well prepared to teach. It is not known if teacher educators can create meaningful, integrative lessons that enable PSTs to learn content and how to teach that content. The aim of this study was, therefore, to investigate the opportunities for explicitly integrating methodology when teaching a content course to PSTs. The questions that guided our study were:

1. How does the teacher educator teach meiosis (a biology topic) to pre-service teachers?
2. What opportunities (if any) of integrating methodology with the teaching of content, are presented in the way the meiosis lecture is taught?
3. What are the pre-service teachers' experiences of the lecture?

1 The term methodology will be used throughout this paper to refer to methods of teaching.

Literature review

What the literature says about the teaching of pre-service teachers at teacher education institutions

According to Zuzovsky and Donitsa-Schmidt (2017), the way in which PSTs are taught is critical because it initiates the PSTs into the teaching profession. In addition, as indicated by Musset (2010), the knowledge and quality of future teachers depends, among other things, on the teaching that occurs in the teacher preparation programmes. As part of improving the way PSTs are prepared for teaching, Rusznyak and Bertram (2021) have argued for a WIL experience that integrates the teaching of visible classroom routines (such as the use of visual representations and various other teaching strategies) as well as the less visible classroom routines that inform a teacher's decisions in the classroom—also known as pedagogic[2] reasoning. The authors (Rusznyak & Bertram, 2021) argued that successful integration of these two components during WIL is essential for PSTs to develop the specialised knowledge that they need to be effective teachers once they are qualified. In this paper, as an extension to the argument by Rusznyak and Bertram (2021) above, we argue that teacher educators should also integrate the teaching of content and methodology, by making explicit the classroom routines as well as the pedagogical reasoning behind the visible actions that they take when teaching PSTs. This is because, according to Pella (2015), engagement with the teacher educator's teaching as well as pedagogical reasoning helps to shift the PSTs' initial content knowledge to PCK. In this way, PSTs would be exposed fully to the content that they are taught as well as how it is being taught.

Teacher professional knowledge

Just as with other professions, there is a knowledge base that a qualified teacher should possess in order to competently and effectively teach learners. According to Carlson and Daehler (2019), teacher professional knowledge comprises of various knowledge bases including content knowledge, pedagogical knowledge, knowledge of students, curricular knowledge, and assessment knowledge. These knowledge bases are essential foundations for teachers to become experts. The integration of content knowledge and the other professional knowledge bases in pedagogical reasoning during teaching contributes to the development of teacher PCK. Many aspects of these teacher professional knowledge bases are taught in methodology courses in teacher preparation programmes and PSTs are expected to integrate them in practice during WIL and after qualification, leading to the development of their PCK. In this study, we are advocating for teacher educators to show the utility of the these knowledge bases by making explicit the pedagogical reasoning behind the classroom routines and actions that they display when teaching content courses to PSTs so as to promote what Mavhunga and Rollnick (2013) described as fast-tracking the development of PSTs' PCK. By giving the PSTs opportunities to delve deeper into their teacher educator's pedagogical

2 Rusznyak and Bertram (2021) used the term *pedagogic reasoning* while Shulman used the term *pedagogical reasoning*. In this study, for consistency with the original source i.e., Shulman (1987), the term pedagogical reasoning will be used.

reasoning, it is envisaged that they are likely to begin to develop their own pedagogical reasoning whilst learning the content that they need to teach.

Pedagogical reasoning

Pedagogical reasoning is a term that Shulman (1987) introduced. It describes the process when teachers use their professional knowledge to make decisions about what to teach and how to teach it (Bishop & Denley, 2007). Pedagogical reasoning is not a simple process of just thinking about teaching (Nilsson, 2009) but, rather, a complex process that occurs in a cycle of six stages, namely, comprehension, transformation, instruction, evaluation, reflection, and new comprehension (Shulman, 1987). *Comprehension* refers to a teacher's understanding of the content in a variety of ways so that they will be in a position to present it in alternative ways when learning difficulties are encountered—as well as an understanding of purpose, of learners, and of ideas within and outside the subject area (Shulman, 1987). *Transformation* is a highly complex process that involves critical interpretation of content to be taught, representation, selection, and adaptation and tailoring of that content. During critical interpretation, teachers engage critically with the subject matter and the teaching material in order to design suitable activities for students. Representation refers to anything that a teacher uses to make the subject matter comprehensible to others. It can be analogies, metaphors, illustrations, examples, explanations, demonstrations, and models (Bishop & Denley, 2007; Shulman, 1986). Selection refers to the choices that a teacher has to make regarding the activities, models, analogies, and so forth, that the teacher will use in the classroom. There are many reasons why teachers would choose certain activities and analogies and not others. Principal among them is the teacher's knowledge of the learners, which includes their cognitive levels, their attitudes, and their predispositions towards the subject matter. The final stage of transformation is adaptation and tailoring. This is a process in which a teacher designs classroom materials and activities specifically for the students in the classroom. It is not a case of "one size fits all." A teacher has to modify the content to be taught to make it suitable for the students in the classroom. The modification may involve a change to a facet of an activity or to the sequence of concepts to be taught. Some of the considerations a teacher has to make include students' prior conceptions, cultural beliefs, gender, ability, and motivation (Geddis & Wood, 1997). *Instruction* follows the process of transformation. It refers to the acts of teaching and learning, which may include the presentations of explanations and descriptions of subject matter, questioning and probing students, answering questions, and discussing with students. *Evaluation* includes teachers checking for understanding in their students as well as looking at their own teaching to assess the effectiveness of the instruction process. *Reflection* is a process where teachers review the teaching and learning that has occurred in the classroom in the light of the educational goals, purposes, and ends that were being sought. Lastly, *new comprehension* refers to the new understanding of content to be taught, of students, of purposes, of self, and of the process of teaching itself that a teacher gains through the acts of preparation, teaching, evaluating, and reflecting (Geddis & Wood, 1997).

As can be seen in the description presented above, every stage involves decision-making by the teacher—making pedagogical reasoning a rich source of teaching insights for teacher educators if it is shared during the teaching of a content course. The description of the pedagogical reasoning cycle above also shows that it is a complex process that is not easy to retrieve by a teacher in a moment. This means that teacher educators may need to practise metacognition if they are to successfully share their pedagogical reasoning with their students. In this study, in order to help the participant to relive the original lecture events and share her pedagogical reasoning, the authors used the video-stimulated recall interview method as described by Vesterinen et al. (2010).

Conceptual framework

To guide this study, we made use of the topic-specific pedagogical content knowledge (TSPCK) framework by Mavhunga and Rollnick (2013), with a focus on one of the three grain sizes of PCK, namely, enacted PCK (Carlson et al., 2019). The TSPCK framework describes knowledge that is required by a teacher in order to adequately reason about the transformation of concepts of a topic into a form understandable by learners, and enacted PCK (ePCK) refers to,

> the specific knowledge and skills utilised by an individual teacher in a particular setting, with a particular student or group of students, with a goal for those students to learn a particular concept, collection of concepts, or a particular aspect of the discipline. (Carlson et al., 2019, p. 84)

The TSPCK framework was chosen because this study focuses on the teaching of one biology topic (meiosis), and it also indicates what teachers need to consider in order to effectively reason about the transformation of the content of a topic into an understandable form. The framework includes the following components: learners' prior knowledge (including misconceptions), appropriate representations (including analogies) of subject matter for that topic, what makes the topic easy or difficult to understand, the place within the curriculum that the topic falls as well as the purpose for teaching that topic (curricular saliency), and conceptual teaching strategies (Mavhunga & Rollnick, 2013).

In this study, using the TSPCK framework as the lens, we examined a teacher educator's enacted PCK when teaching meiosis. We focused on the manifestations of the components of TSPCK as offering opportunities for integrating methodology during the teaching of a content topic.

Research methods and design

Research approach

This was a case study that allowed for the exploration of both the process and the outcome of a complex phenomenon, namely, teaching in the real world (Harrison et al., 2017; Zainal, 2007) which, in this case, was the teacher educator's classroom. We explored a teacher

educator's teaching of meiosis as well as the outcome in terms of the opportunities for the integration of teaching content and methodology, and what the PSTs experienced about the teaching of meiosis. The study was an exploratory case study because we explored the pedagogical practices of the teacher educator that allowed for the integration of methodology when teaching content. This was a qualitative study because it focused on understanding and exploring phenomena through "organising data into categories and identifying patterns (relationships) among categories" (McMillan & Schumacher, 1993, as quoted in Astalin, 2013, p. 118). Teacher educators' ePCK, pedagogical reasoning, and student experiences are examples of phenomena that were explored in this study.

Setting of the study

The setting of our study was a South African university that uses a unique concurrent model of training secondary school teachers. The model is unique in that the content courses are taught along with the methodology courses in the same school of education. This means that, every week, a PST at this university has periods allocated for attending content courses and periods for attending methodologies and this is the arrangement from first year up to fourth year. However, it is important to note that, although the programme delineates the teaching of methodology courses in relation to content majors, what is taught in methodology courses may not necessarily be linked to the content that is covered in the content courses. For example, students being taught the topic of genetics in the content course may not be taught how to teach genetics, namely, skills and competences associated with the teaching of genetics. In addition, the content and the methodology courses at each level are not necessarily taught by the same teacher educator, meaning that one teacher educator may be teaching the content course while a different teacher educator teaches the methodology course. The teacher educator who participated in this study was teaching a life sciences content course (focusing specifically on the topic of genetics including meiosis) to fourth-year PSTs training to be life sciences secondary school teachers.

Population and sample

The participants in the study were one teacher educator and 130 fourth-year pre-service teachers who were registered for the genetics course. Fifteen of the PSTs gave their consent to participate in focus group interviews.

Data sources and collection

Data sources for this study were video recordings of three 50-minute meiosis lectures taught by the teacher educator, and video-stimulated recall (VSR) interviews with the teacher educator to determine the pedagogical reasoning behind the practices observed in the lectures. Audio-recordings of focus group interviews with the PSTs were also collected, which aimed to determine their experiences of the lectures and to see what pedagogical practices they had learned from the course. Although the average number of participants in focus group interviews is usually between four and six, our focus group interview consisted of 15 participants. This is because when we approached the class with the request, 15 PSTs

showed interest and consented to taking part in the interview. All 15 then indicated that they wanted to do the interview on the same day, after class, and be done with it because it was the last day of the genetics lectures. Seeing their immediate availability and readiness to do the interview, we could not divide the group and send others away to find another time for the interview. Therefore, we decided to interview all 15 PSTs at one go. In order to overcome the negative effects of large focus groups, we made sure to give each PST an equal opportunity to express their opinions. This was done by allowing each PST to respond to the questions that we were posing and to say what they wanted to say. Allowing each participant to have a voice helped to reduce bias within the interview.

Data analysis

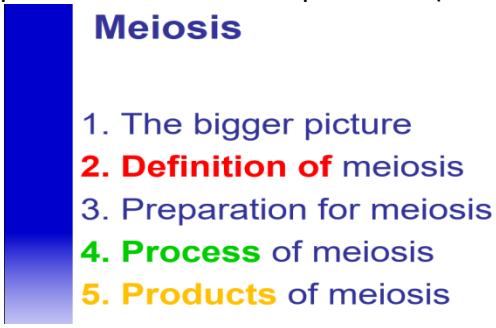
The analysis and coding of the three data sets mentioned above was deductive because they were guided by the TSPCK model.

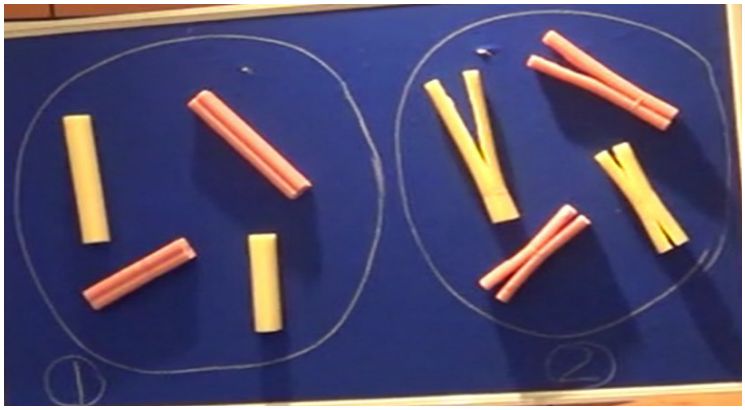
Analysis of video recordings

We familiarised ourselves with what transpired in the lecture by watching each recorded lecture twice. We then transcribed the video, during which we wrote out the audio and took screen shots of important aspects about the teaching process. The choice of the important aspects was informed by the conceptual framework—specifically, the various stages and aspects of pedagogical reasoning as described earlier. After transcribing, we coded the transcripts. As indicated above, our method of analysis was deductive because it was guided by the different aspects of the TSPCK model as well as the various aspects of the pedagogical reasoning cycle. However, we were open to new aspects that arose during analysis that were not covered by our initial framework and from those, we incorporated an inductive research analysis approach (Gabriel, 2013) as we progressed. See Figure 1 for an excerpt of a coded transcript.

Figure 1

Excerpt of coded video transcript (TE = Teacher educator)

Coding **TE**: **T**eacher **E**ducator	
TE	So, this is what we are going to look at, what meiosis is, preparation for meiosis, process of meiosis and products. (**Curricular Saliency – CS**)  **Comment**: Content selection is an aspect of pedagogical reasoning.

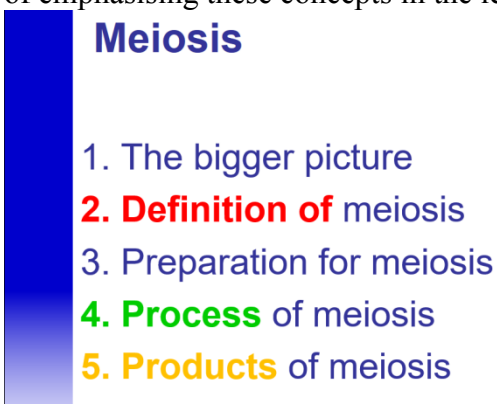
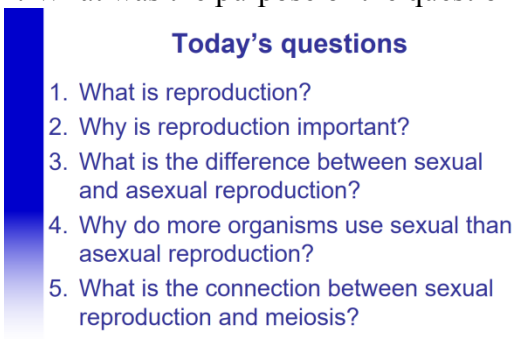
Coding **TE**: **T**eacher **E**ducator	
TE	Meiosis is linked to reproduction; we want to be clear on some things before we go into detail (**Teaching strategy-Q & A – Question and answer session**) **Today's questions** 1. What is reproduction? 2. Why is reproduction important? 3. What is the difference between sexual and asexual reproduction? 4. Why do more organisms use sexual than asexual reproduction? 5. What is the connection between sexual reproduction and meiosis? **Comment:** Selection of an instruction strategy, an aspect of pedagogical reasoning.
TE	 **Subject matter representation – SMR** **Comment:** Selection of pool noodles as representations and designing learning material, an aspect of pedagogical reasoning.

Analysis of VSR interviews and focus group interviews

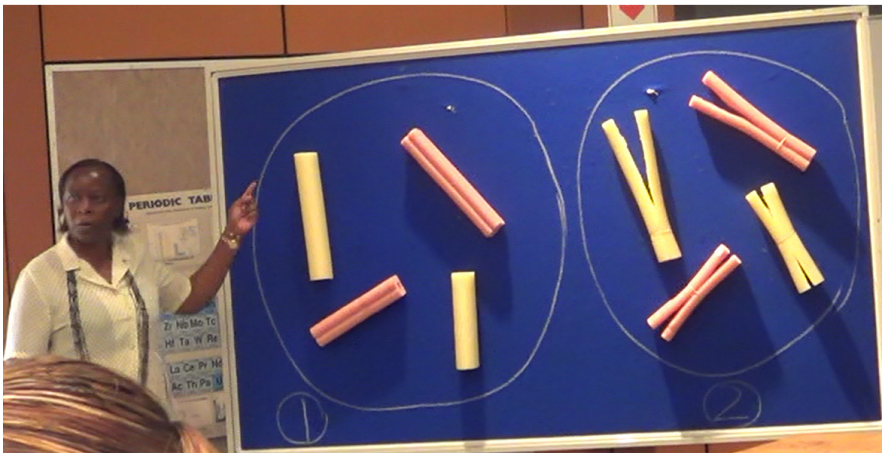
As with the video recordings, we deductively coded the interview transcripts using the TSPCK framework as a guide. Figure 2 is an excerpt of a coded transcript of the VSR interviews with the teacher educator. An excerpt of a coded transcript of the focus group interviews can be seen in Figure 3.

Figure 2

Excerpt of coded VSR interview (TE = Teacher educator)

Interview Excerpt **I:** Interviewer **TE**: Teacher Educator
I: You presented the outline of meiosis shown in this screen shot. What was the purpose of emphasising these concepts in the lecture? 
TE:Those cover the whole objective of teaching and learning that topic (**Curricular saliency - CS**). So, I want them to be clear on what the objectives are, so when I say this is preparation, they are already able to see so what we mean by preparation, what happens during preparation? When we look at processes, they will look at the whole process of meiosis to see how this purpose is achieved. So, it was structured so that when they are constructing their own knowledge, it's already structured for ease of storage and retrieval (*pedagogical reasoning (PR) behind how the TE structured the content for teaching*).
I: What was the purpose of the questions asked at the beginning of the lecture? 
TE: The questions were on reproduction and reproduction is directly linked to meiosis (**Curricular saliency**). So, I wanted the students to see the link (*PR)*. What we call curricular saliency (**CS**). i.e. why do we look at meiosis and what other topics and concepts do you need to know that will help you to understand meiosis. If I teach the topic in isolation, they won't see the relevance, so by asking those question I wanted them to see, oh meiosis is linked to reproduction (*PR behind today's questions-discussing the connection between the process of reproduction and meiosis so that students can see the relevance of the topic*).
I: How did you come up with the idea to use pool noodles as representations for meiotic processes? And why did you use these?

Interview Excerpt
I: Interviewer **TE**: Teacher Educator



TE: It was really just creativity. I got the idea of using pool noodles when I was struggling to figure out visuals that students in a big lecture room can see. The number of students in my class was increasing **(Context of TE - CTE)**. Previously I would have 30 students, so other things like thread would work to show the behaviour of chromosomes, but eventually the number of people increased and went on to 40, to 80 and this year I have 130. So, I can't use a thread or a string to represent all the different aspects that I wanted them to see **(CTE)**. So, a colleague said why not use pool noodles? They can be seen right from the end of the lecture. And when I got the pool noodles **(subject matter representation - SMR)**, that's when creativity set in. I realised that I could actually cut them and build structures that would help them to see that initially we don't see chromatids although each chromosome will be made up of chromatids **(Subject matter representation - SMR)**. Then we can move as they shorten and thicken. So, making up those structures was my creativity trying to figure out how best to use materials. So now I actually use so many different materials that I use to model genetics concepts. I no longer buy readymade models. Now I focus more on every day stuff, materials that students can get. Again, for the purposes of them seeing that you can be creative, that you can use every day items **(Context of students COS)** (*PR behind the choice and use of pool noodles and other easy to get materials instead of ready-made materials*).

I: Why do you probe students to answer questions instead of giving them the answer? **(Probing students - PR)**

TE: It's sort of a constructivist approach where they need to construct their own knowledge (*PR*). So, if I just tell them, then it's like pouring the knowledge into their heads instead of them constructing their own knowledge. And in addition, for my teaching to be effective, I want to start from what they know (**an indication that the lecturer is aware that students bring in prior knowledge**), so when I ask a question and they say something, immediately I use that response to build on their understanding, although it does show immediately in my actions, when I listen to the answers, in my mind, I will be assessing what is correct and what is wrong and I'm trying to figure out what it is the student's thinking. So that in the process of probing, I am pushing them to think further (*PR*), I can eventually correct the misconceptions as well as add to the knowledge that they have (*PR behind probing students for answers-to facilitate knowledge construction*).

Figure 3

Excerpt of coded focus group interview

Focus Group Interview Excerpt	
Interviewer	Describe a typical meiosis lecture session
Student 1	She brought strings **(subject matter representation - SMR)** to illustrate the difference between chromosomes and chromatin network (Teaching strategy - TS)
Student 2	There's just a lot of visuals **(subject matter representations)** compared to other lectures
Interviewer	What types of content and skills have you encountered so far?
Student 8	I think with meiosis we had to first go through what we already know, the prior knowledge. And the prior knowledge was focused on the differences between meiosis and mitosis **(student interprets what the TE did and concluded that it was to determine prior knowledge)** and then we moved on to the actual stages of meiosis and in meiosis we had to differentiate between the two stages of meiosis and be able to label it.
Student 6	She would give us a lot of activities (**Teaching strategy**). So, she would give us a worksheet and there will be questions for us to answer before so that she can see what kind of content to proceed with us. So, in most cases, she wanted to refer to what we know (TE used worksheet with questions as a strategy to determine students' prior knowledge). And then discussions (teaching strategy)
Interviewer	What messages about teaching and learning did you understand from meiosis classes?
Student 2	I think that in her lectures she catered for everyone in the sense that there will be a theory part where most people would just go through theory and understand , there would be a video that we watched of her lecturing, and if you did not understand the lecture, you would maybe watch and listen to the video that was on Sakai. And then also the visual aids **(subject matter representation - SMR)** that she used. So, she used different strategies to teach one thing so that she probably meets everyone's understanding **(TE varied teaching strategies that she used-an indication of an awareness that students have different learning styles - LS)**

Ethical considerations

The research study was formally approved by the ethics committee of the faculty of education at the South African university at which the study was conducted (Protocol Number: 2019ECE065H). All ethical requirements were adhered to. Permission to conduct the study with fourth-year PSTs at the institution was granted by the university head of school. The participants were given a cover letter that clarified the purpose of the study and the nature of the research, and each participant signed an informed consent form giving permission to include them in the research. To ensure that all information given was kept confidential, access to the data was restricted to the authors of this paper only, and responses to interviews were not shared with anyone else. To ensure anonymity of the participants, participants were not required to use their names during the interview and non-identifiable labels were used when responses were used for the final write up of the study. Participants were aware that they could withdraw from the study at any time. Arrangements were made for interviews to take place at a time and venue that was convenient for all participants.

Presentation of findings and discussion

The results of this study showed that:

1. The teacher educator taught by using a variety of teaching strategies and representations.
2. There were many opportunities for integrating how to teach meiosis methods while teaching the meiosis content.
3. Pre-service teachers' experiences of the lecture included experiences of the teaching strategies and representations that were used by the teacher educator, which seem to have created opportunities for the PSTs to reason about the teaching they were experiencing.

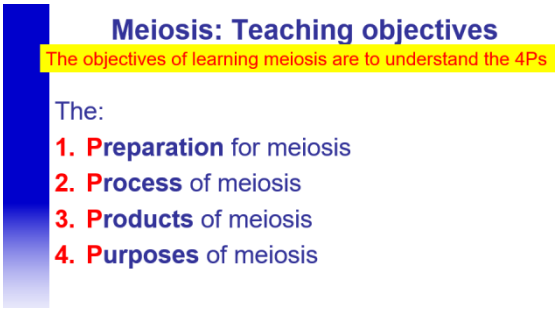
Results from the analysis of interviews with the teacher educator

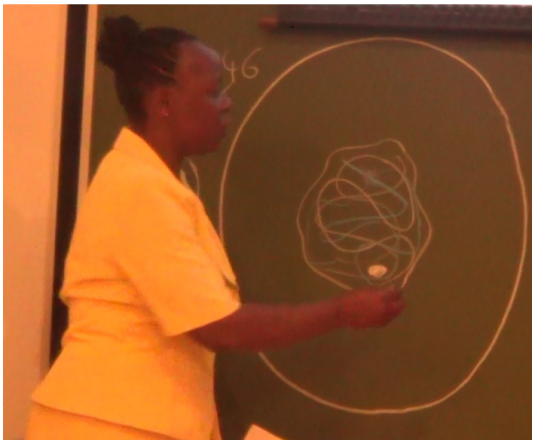
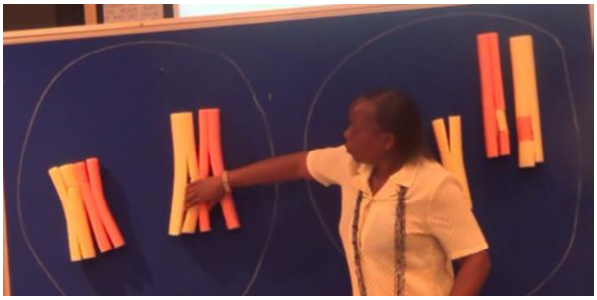
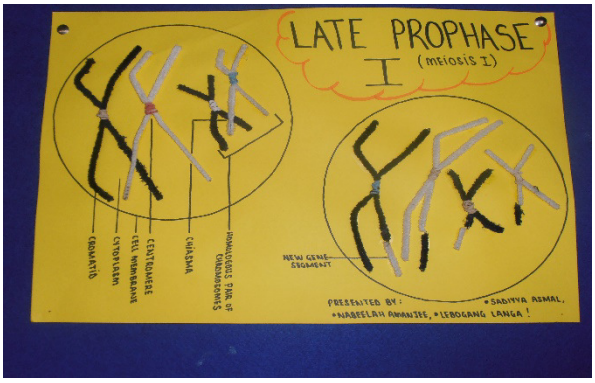
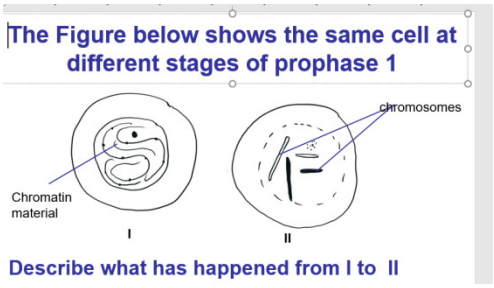
Use of subject matter representations

The analysis of the video-recorded lectures showed explicit manifestation of subject matter representations in the teacher educator's ePCK. The teacher educator made use of multiple subject matter representations, the visible classroom routines (Mavhunga & Rollnick, 2013; Rusznyak & Bertram, 2021) including a PowerPoint presentation, diagrams on the chalkboard, pool noodles on a board, posters, and hand-drawn labelled diagrams. These subject matter representations can be seen in Figure 4.

Figure 4

Subject matter representations used by the teacher educator throughout the lecture

Example	Picture
PowerPoint Presentation	

Example	Picture
An illustration on the chalkboard	
An illustration using pool noodles	
Posters	
Hand drawn diagrams	

As can be seen in Figure 4, classroom routines (Rusznyak & Bertram, 2021) were present in the lectures for PSTs to see. The PowerPoint presentation was the central visual aid used throughout the lectures. Use of a PowerPoint presentation was central to the teacher educator's teaching because of, according to her, its diverse and flexible nature as a visual aid. She can choose the font as well as the size and colours of that font, add pictures and diagrams, and adjust the layout of the slides as needed. She indicated that all of these factors aid in grasping the attention of the students so that they are able to focus on the subject matter

in front of them and concentrate on understanding the concepts that are being taught without getting bored or losing sight of what it is they are learning. Instead of presenting the PSTs with slides full of writing, the teacher educator introduced new concepts on the slides point-by-point, and made use of pictures and diagrams so as not to overwhelm the PSTs with too much information at once while also getting the point across. This pedagogical reasoning behind the ePCK is what Rusznyak and Bertram (2021) described as the less visible routine, which is crucial and must be made accessible to PSTs for better learning gains. The teacher educator did not, however, make known to her class this crucial pedagogical reasoning aspect of her enacted PCK. Hence, it remained inaccessible to PSTs, which we viewed as a missed opportunity for integrating the teaching of content and methodology.

In addition to the use of PowerPoint presentations, the teacher educator illustrated certain concepts through writing on a chalkboard. The teacher educator's pedagogical reasoning for this was:

> To show diversity in the visual aids that can be used in the classroom as well to develop and build conceptual understandings together with the pre-service teachers.

The teacher educator also made use of pool noodles on a board, which was a creative way of using every day household objects to create an impactful visual aid. According to the teacher educator:

> The illustrations done using pool noodles are big enough to be seen throughout the lecture theatre and they succinctly represent the behaviour of chromosomes during meiosis, specifically synapses and crossing over. In addition to showing pre-service teachers a clear representation of the content, the illustration also shows PSTs that they do not need to spend a lot of money buying ready-made models to demonstrate processes, but they have the ability to make use of every day, easy-to-find objects.

The teacher educator also reasoned that because the class size was growing, use of smaller representations like pipe cleaners was no longer suitable because they cannot be seen by everyone; she had to think out of the box to get a bigger representation that could be seen throughout the class. The teacher educator therefore also showed a consideration of the changing learning context in her pedagogical reasoning. All of these invisible classroom routines are opportunities for integration of methodological aspects that should be made visible to PSTs during the teaching of a content course.

Other subject matter representations used by the teacher educator to demonstrate certain processes were strings and posters. These, along with question-and-answer sessions, were used to represent the importance of the formation of chromosomes because these concepts are often difficult for PSTs to understand. The teacher educator used analogies throughout the lecture in order to give PSTs the ability to relate new concepts to experiences that were familiar to them. As the teacher educator said:

> It becomes easier for them to remember because they are able to identify the unfamiliar concept with the known and familiar analogy.

Use of conceptual teaching strategies

The teacher educator made use of multiple teaching strategies including probing the PSTs for answers, initiating class discussions, making reference to textbooks and what is easy or difficult to teach, and identifying learner prior knowledge (which Mavhunga & Rollnick, 2013, highlighted as important aspects of TSPCK for effective teaching). Throughout the lecture, the teacher educator probed the PSTs to answer questions instead of her giving them the answers, and she provided her pedagogical reasoning behind the probing aspect in the video-stimulated recall interview:

> Probing allows PSTs to verbalise their thinking and, in the process of interaction, to construct their own knowledge.

The teacher educator therefore made use of a constructivist approach during her lectures to provide opportunities for PSTs to build on their understanding of the concepts that were being taught. Through probing, the teacher educator said that she was pushing the PSTs to think further. In addition, probing provided opportunities for PSTs to verbalise their ideas and thinking, thereby enabling the teacher educator to address any misconceptions that the PSTs might have. In this way, the teacher educator was gaining an understanding of the prior knowledge of the PSTs (including misconceptions), and she was then able to add to the knowledge that the PSTs already had. In addition to probing, after explaining certain content, the teacher educator would give the PSTs time to discuss what they had learned amongst themselves, and her reasoning was:

> It is only when you verbalise your thinking that you know whether you have understood the concept or not.

The teacher educator also made reference to errors in school textbooks during the lecture in order to:

> Highlight some of the weaknesses in the text books that can lead to misconceptions.

Throughout the lecture, the teacher educator emphasised the importance of understanding certain terms. The video-stimulated recall interview showed that the teacher educator knew which terms and concepts to emphasise through extensive reading of the research literature on genetics teaching and learning. By reading literature, the teacher educator was aware of problematic terminology that learners might find difficult to understand (knowledge of the learning context). Aside from emphasising the important terms, the teacher educator also made sure to mention and explain the links between the topics of meiosis and genetics and where DNA, chromatin, and chromosomes fit in. By emphasising these during the lecture, the teacher educator ensured that the PSTs were able to understand the terms and concepts as well as their importance, which will be essential when they teach their own learners. The teacher educator decided to explain the complicated terms before beginning the lesson on

meiosis in order to create fluidity within the lecture. Once the teacher educator had begun to teach, she would just mention these terms without having to interrupt the flow of the lesson to explain the terminology. It is clear to see that the ePCK had many opportunities that could be drawn on for purposes of integration. These processes and reasoning were however, never made explicit to PSTs.

Curricular saliency

A teacher is said to display curricular saliency through their decisions of which aspects of the topic that they are teaching they choose to include or withdraw when teaching. They also need to understand how the topic of interest fits into the overall curriculum (Rollnick et al., 2008). The teacher educator demonstrated curricular saliency throughout the lecture in various ways, namely, linking meiosis to reproduction through a question-and-answer session, emphasising specific terms, analogies, and deciding what was essential for the lecture. Curricular saliency also manifested throughout the teacher educator's teaching as the teacher educator made links between specific topics and chose what content to focus on and what content to leave out of the lectures. Again, all of these manifestations of curricular saliency were opportunities that the teacher educator could have used to integrate and emphasise the importance of curricular saliency, a methodological aspect, during the teaching of content.

Results from the analysis of the focus group interview

An analysis of the focus group interview showed that PSTs gained knowledge of the use of subject matter representations from the meiosis lecture. When asked if they felt that they would be able to teach meiosis after these lectures, the PSTs reacted positively with certain PSTs stating they felt that they would be able to use the different subject matter representations to teach meiosis effectively to their own learners:

> Student 3: She made lots of learning aids for us to use, for each stage of meiosis . . . and you can use them, for example, representing chromosomes in a Grade 10 class . . . bringing a representation to every class and not just a picture, it gives you the 3D and it allows you to actually picture what the abstract chromosomes look like.
>
> Student 4: We would use the same visual aids that she used.
>
> Student 13: For me, in terms of representations, I feel like I am prepared [to teach].

The PSTs' utterances show that while they were learning the content of meiosis, they were also learning different ways of representing meiosis concepts from their experiences of the teacher educator's ePCK—the visible routines. The PSTs gained what Rusznyak and Bertram (2021) described as an understanding of how the teacher educator conducts a lesson. In a number of instances, PSTs reasoned about the observed classroom routines:

> By asking probing questions, the teacher educator wanted to go through what we know and wanted to determine our prior knowledge.

Instances of pedagogical reasoning such as this one could be seen several times in PSTs' interview transcripts. In the instance above, PSTs showed an awareness that the teacher educator could be determining their prior knowledge. This reasoning aligned with the teacher educator's reasoning:

> For my teaching to be effective, I want to start from what they know, so when I ask a question and they say something, immediately I use that response to build on their understanding . . . when I listen to the answers, already I am seeing what is correct, what is wrong and I'm trying to figure out what is the student's thinking. So that in the process of probing, I am pushing them to think further, I am able to correct the misconceptions and to add to the knowledge that they have.

As can be seen above, the students' and the teacher educator's reasoning are similar. Therefore, if the teacher educator could integrate this thinking in her teaching by making it explicit to her class, that would confirm their interpretation of the teacher educator's classroom routines—thereby possibly achieving what Pella (2005) described as a shift from content knowledge to PCK. Making PSTs aware of the pedagogical reasoning can lead to the PSTs understanding the importance of doing certain classroom routines when teaching such as using a question-and-answer strategy. It also shows PSTs how to use a question-and-answer strategy and build on learners' prior knowledge, which are strategies that they can apply in their own classrooms after qualification. Therefore, PSTs can learn the techniques for teaching their own learners in a content course.

In their interviews, the PSTs made mention of the teacher educator's strategy of pointing out misconceptions in the textbook. For example, Student 10 said:

> In some schoolbooks, there are a lot of misconceptions so, with this lecture, we've gotten to understand that. This is how it actually happened rather than what we were taught in high school.

In this manner, we could see that the teacher educator was linking content to pedagogy because, while teaching the content of meiosis, she was also pointing out to the PSTs how to recognise certain misconceptions in order to not pass those misconceptions on to their future learners. This is an instance of integration of methodology during the teaching of content.

Although the PSTs might not know what curricular saliency is, and the teacher educator did not mention curricular saliency during the lecture, the PSTs were still aware of the structures that the teacher educator was putting into place during the lecture. Furthermore, the subject matter that the teacher educator covered in the lecture was aligned to the meiosis content that is covered in the Curriculum Assessment Policy Statements (CAPS) curriculum. PSTs, however, did experience curricular saliency:

> Student 4: We started with learning the phases of meiosis.

> Student 2: We learned why meiosis occurs.
>
> Student 8: I think with meiosis we had to first go through what we already know, the prior knowledge. And the prior knowledge was focused on the differences between meiosis and mitosis and then we moved on to the actual stages of meiosis and, in meiosis, we had to differentiate between the two stages of meiosis and be able to label it.

The PSTs' responses above present an opportunity for integration of teaching content and methodology because through the teacher educator's process of teaching all the concepts of meiosis and determining what the PSTs did and did not know, the PSTs could learn the content that they needed to know and the order in which to teach it, and they could also see what they needed to cover and do in order to teach meiosis to their own future learners. The teacher educator's curricular saliency therefore allowed the PSTs to know and understand essential concepts, different techniques to teach, as well as how to structure those concepts in order to portray this knowledge to their learners. The teacher educator's pedagogical reasoning behind these curricular saliency concepts was, however, again not made explicit—indicating a missed opportunity for integrating methodology during the teaching of content.

Conclusions and recommendations

The problem that motivated this study was that many teacher education programmes are structured such that content and methodology are taught separately. This makes it difficult for PSTs to develop pedagogical content knowledge in an integrated manner (Nyamupangedengu & Lelliott, 2018). It had not been determined whether, if teacher educators were able to create meaningful and integrative lessons, that would help PSTs to learn content as well as how to teach that content. The purpose of this study was therefore to investigate if a teacher educator teaching a content course to fourth-year PSTs could integrate methodology aspects, or if there were opportunities during the teaching of content for integrating methodology aspects. The key findings of the study showed that the teacher educator created many opportunities for integrating how to teach meiosis (methodology) while teaching the meiosis content through the use of visible classroom routines (including PowerPoint presentations, writing on a chalkboard, pool noodles on a board, strings, posters, and analogies). The teacher educator also used conceptual teaching strategies such as probing the PSTs for answers, initiating class discussions, making reference to textbooks and what is easy or difficult to teach, and identifying learner prior knowledge, which are important aspects of TSPCK for effective teaching (Mavhunga & Rollnick, 2013). Curricular saliency also manifested throughout the teacher educator's teaching as the teacher educator made links between specific topics and chose what content to focus on and what content to leave out of the lectures. The teacher educator's pedagogical reasoning was revealed through video-stimulated recall interviews. The pedagogical reasoning and the use of the strategies above demonstrates the opportunities that the teacher educator created that could be used to integrate the teaching of content and methodology.

The use of multiple teaching strategies created these integration opportunities, resulting in PSTs gaining PCK through observing how the teacher educator was teaching (visible classroom routines). PSTs collectively showed a positive response to the different strategies used in the content lecture, stating that they felt they would be able to teach their own learners using these strategies. In several instances, the PSTs were able to appropriately reason about the purposes of the teaching strategies that the teacher educator was using. This appropriate reasoning by PSTs shows that the teaching strategies that teacher educators use are opportunities that can be used to develop PSTs' PCK during the teaching of content. The study showed that consideration and application of the TSPCK components during both the planning and the teaching enabled the integration of methodology in the teaching of content by the teacher educator. This study therefore showed that it is possible to integrate the teaching of methodology with the teaching of content. The study, however, recommends that the teacher educator's pedagogical reasoning behind the teaching strategies and the choice of representations be made explicit to allow PSTs to reflect and critically engage with the teacher educator's teaching. It is envisaged that this approach would further support the learning about teaching that PSTs gain through their experiences of the visible classroom routines.

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References

Astalin, P. K. (2013). Qualitative research designs: A conceptual framework. *International Journal of Social Science & Interdisciplinary Research, 2*(1), 118–124. http://indianresearchjournals.com/pdf/IJSSIR/2013/January/13.pdf

Bishop, K., & Denley, P. (2007). *Learning science teaching: Developing a professional knowledge base*. Open University Press.

Carlson, J., & Daehler, K. R. (2019). The refined consensus model of pedagogical content knowledge in science education. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp. 77–94). Springer. https://doi.org/10.1007/978-981-13-5898-2_2

Gabriel, D. (2013, March 17). *Inductive and deductive approaches to research*. http://deborahgabriel.com/2013/03/17/inductive-and-deductive-approaches-to-research/

Garbett, D. (2012). The transformation from expert science teacher to science teacher educator. In S. M. Bullock & T. Russell (Eds.), *Self-studies of science teacher education practices* (pp. 31–44). Springer.

Geddis, A. N., & Wood, E. (1997). Transforming subject matter and managing dilemmas: A case study in teacher education. *Teaching and Teacher Education, 13*, 611–626. https://doi.org/10.1016/S0742-051X(97)80004-2

Harrison, H., Birks, M., Franklin, R., & Mills, J. (2017). Case Study Research: Foundations and Methodological Orientations. *Forum: Qualitative Social Research*, *18*(1). https://doi.org/10.17169/fqs-18.1.2655

Mavhunga, E., & Rollnick, M. (2013). Improving PCK of chemical equilibrium in pre-service teachers. *African Journal of Research in Mathematics, Science and Technology Education, 17*(1/2), 113–125. https://doi.org/10.1080/10288457.2013.828406

Murray, J. (2005). Re-addressing the priorities: New teacher educators and induction into higher education. *European Journal of Teacher Education, 28*(1), 67–85. https://doi.org/10.1080/02619760500040108

Musset, P. (2010). *Initial teacher education and continuing training policies in a comparative perspective: Current practices in OECD countries and a literature review on potential effects* (Working Paper No.48). OECD Publishing.

Nilsson, P. (2009). From lesson plan to new comprehension: Exploring student teachers' pedagogical reasoning in learning about teaching, *European Journal of Teacher Education, 32*(3), 239–258. https://doi.org/10.1080/02619760802553048

Nyamupangedengu, E., & Lelliott, A. (2018). Planning for teaching a genetics course to pre-service teachers: Experiences of a biology teacher educator. *African Journal of Research in Mathematics, Science and Technology Education, 22*(3), 308–318. https://doi.org/10.1080/18117295.2018.1539325

Pella, S. (2015). Pedagogical reasoning and action: Affordances of practice-based teacher professional development. *Teacher education Quarterly, 2*(3), 81–101. https://files.eric.ed.gov/fulltext/EJ1090800.pdf

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education, 30*(10), 1365–1387. https://doi.org/10.1080/09500690802187025

Rusznyak, L., & Bertram, C. (2021). Conceptualising work-integrated learning to support pre-service teachers' pedagogic reasoning. *Journal of Education, 83*, 34–53. http://dx.doi.org/10.17159/2520-9868/i83a02

Sederevičiūtė-Pačiauskienė, Ž., & Vainorytė, B. (2015). The concurrent and consecutive models of initial teacher training: Problematics and tendencies. *Rural Environment Education, 15*, 347–354. https://llufb.llu.lv/conference/REEP/2015/Latvia-Univ-Agricult-REEP-2015proceedings-347-354.pdf

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://www.wcu.edu/webfiles/pdfs/shulman.pdf

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–15. https://people.ucsc.edu/~ktellez/shulman.pdf

Vesterinen, O., Toom, A., & Patrikainen, S (2010). The stimulated recall method and ICTs in research on the reasoning of teachers. *International Journal of Research and Method in Education, 33*(2), 183–197. https://doi.org/10.1080/1743727X.2010.484605

Zainal, Z. (2007). Case study research method. *Jurnal Kemanusiaan,* 9. https://core.ac.uk/download/pdf/11784113.pdf

Zuzovsky, R., & Donitsa-Schmidt, S. (2017). Comparing the effectiveness of two models of initial teacher education programmes in Israel: Concurrent vs consecutive. *European Journal of Teacher Education, 40*(3), 413–431. https://doi.org/10.1080/02619768.2017.1318377