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Chapter 8
Investigating Abstractness and Motivation as Scaffolding Elements in Biology Lesson Planning. An Explorative Study.

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In this chapter, we focus on lesson planning as one general competence that the biology education program at the University of Tübingen in Germany and the South African University of the Witwatersrand's School of Education (WSoE) aim to develop in teaching students. We first provide an overview of biology teacher education at Wits and Tübingen. We then present a case study in which teaching methods based on the cone of learning and practical teaching methods at Tübingen University are implemented for the school topic 'ecology and evolution'. We provide the results of a lesson plan analysis, showing that only about half of the students at Tübingen University were able to apply the knowledge from the introductory lecture to their practical lesson plans. Using the cone of learning helps to show the kinds of representation chosen by the students, but does not illuminate teaching students' pedagogical reasoning for the choice of representations. Because of this, the study recommends a mixed method approach, in which the analysis of lesson plans using the cone of learning is followed by the interviewing of the teaching students.

1 Introduction

"Failing to plan is planning to fail" is an age-old adage that highlights the importance of planning in life. Even in education, lesson planning is considered to be central to good teaching and is a core activity in schools (Kosnick & Beck, 2009). Because of its

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importance, preparing student teachers to plan instruction that meets the learning needs of their pupils is one goal of teacher education programs (Rusznyak & Walton, 2011). Teaching student teachers how to create lesson plans is therefore one of the key activities in pre-service teacher education (Kosnick & Beck, 2009; John, 2006). While the importance of lesson planning is widely recognized, research shows that effective lesson planning is a significant challenge for pre-service teachers (Derri, Papamitrou, Vernadakis & Koufou, 2014). One reason for this is the inability of teacher educators to strike a balance between providing lesson plan guidelines that can easily be used by student teachers while preserving what Rusznyak and Walton (2011, p. 272) describe as "the complexity that reveals the inner logic of lesson coherence". According to Rusznyak and Walton (2011), one way of overcoming this challenge is by scaffolding the student teachers' development of lesson-planning skills. This suggestion, however, raises the question of how that scaffolding can be achieved. In this collaborative research, the authors analyzed teaching students' lesson plans at Tübingen University to determine the effectiveness of the concepts of the cone of learning and biologically relevant methods as scaffolding tools for developing teaching students' ability to prepare effective lesson plans, drawing on insights from WSoE experiences in which a specific framework was used. Effective lesson plans were taken to be those that reflect not only aspects of good teaching, as outlined by the cone of learning and the biologically relevant methods, but also coherent pedagogical reasoning (Bishop & Denley, 2007) about the choice of instruction. Through document analysis, the basic ideas of biology teaching that manifested in the lesson plans were compared with what was taught by the educators and discussed in relation to the lesson planning approaches used at the University of the Witwatersrand's School of Education (WSoE). The questions that guided this study were:

1. How do the concepts of the cone of learning and of biologically relevant methods used in the Tübingen Biology Education Department support the scaffolding of lesson planning?
2. How do the concepts of the cone of learning and of biologically relevant methods used in Tübingen relate to the TSPCK framework used in the WSoE?

2 Context of the study: An overview of biology teacher education at Wits and Tübingen

The teacher education program at WSoE is made up of four streams: the academic stream, which covers the teaching of disciplinary content subjects, such as mathematics, science, geography and English; the core subjects stream, which consists of the philosophy, psychology and sociology of education; the pedagogical stream, which covers courses on teaching methods referred to simply as methods courses; and the Teaching Experience stream. In the content stream, pre-service teachers are taught subject-specific knowledge. In the core subject stream, they are taught about education and its foundations and theories. In the methods courses, they are taught how to teach a specific content subject. Lastly, in the Teaching Experience stream, students are placed in schools to practice teaching (for further details on the program, see Nyamupangedengu, 2016 and Mavhunga & Rollnick, 2017). In the Division of Science Education, the pedagogical stream, i.e., the teaching of the methods courses, is guided by a pedagogical content knowledge framework called the Topic Specific Pedagogical Content Knowledge (TSPCK) framework.

There are several similarities between the WSoE and the TüSE. Similar to the WSoE's first stream, Tübingen has a strong foundation in the content subjects. Unlike at the WSoE, this content is taught separately from biological education teaching, but with overlap in some topics, such as ecology and evolution. Furthermore, a second column consists of core subjects such as the philosophy, psychology and sociology of education. The TüSE's third stream is made up of "Fachdidaktik", a term rather difficult to translate, as it refers to teaching a specific subject. Fachdidaktik combines methodological questions with subject-specific content.

To illustrate this: the topic of animal ecology is related to the content stream at the WSoE, while topics like classroom management or optimal group size are related to the core subjects stream. However, Fachdidaktik is about the teaching of specific content that is not taught in other streams. Microscopy or observation of living animals, for instance, are rarely taught in other subjects. These courses are partly comparable between both universities because they link scientific content with practical teaching. An example is "biology lessons planning", in which different methods are taught. Thus, the subject courses for biology teaching students are similar to Bachelor of Science courses in terms of biological content. However, the methodology is different for biology teaching students' courses, and teaching students receive additional courses in biology teaching methods and didactical aspects.

Other science subjects also differ in content and subject-specific teaching, while all teaching students experience more or less similar courses in education sciences. As in the fourth stream, the TüSE also has mandatory teaching experience, which is, however, placed in the master's program. It comprises about 16 weeks of teaching in regular schools and is supervised by teachers.

2.1 Literature review and the analytical framework for the study

As indicated in the context section above, the teaching of biology methodology courses at the WSoE is guided by the TSPCK framework. In 2009, Shen, Poppink, Cui and Fan identified pedagogical content knowledge (PCK) as knowledge that teachers need in order to plan effective lessons. PCK was defined by Shulman as a special amalgam of content and pedagogy needed for teaching the subject. Shulman further wrote that PCK, in terms of the most regularly taught topics in one's area, includes:

> » The most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations---in a word, the ways of representing and formulating the subject that makes it comprehensible to others. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (Shulman, 1987, p. 8).

In 2013, Mavhunga and Rollnick argued that PCK is topic-specific, developing the Topic Specific Pedagogical Content Knowledge (TSPCK) framework. The TSPCK framework describes knowledge that teachers can use to transform content into a form understandable to learners (Mavhunga & Rollnick, 2013). With its five components—curricular saliency, learner prior knowledge (including misconceptions), what is difficult to teach, representations (including analogies) and conceptual teaching strategies—TSPCK provides ways for content to be successfully transformed for teaching during planning and instruction.

Learner prior knowledge describes the preconceptions that learners bring with them to a learning environment. Curricular saliency is a teacher's ability to identify the big ideas of a topic and its subordinates, sequence them, and grasp their importance. What is difficult to teach refers to whatever makes the learning of specific topics difficult. Representations including analogies refers to illustrations, examples, explanations and demonstrations. Conceptual teaching strategies refers to the knowledge of teaching strategies most likely to be effective when teaching a specific topic. These five components assist teachers in considering what learners already know about a topic, the big ideas it involves, as well as a consideration of the knowledge that learners should possess in order to understand the topic. Mavhunga and Rollnick (2013) have shown that TSPCK can be used to fast-track the development of PCK in pre-service teachers. As has already been indicated, the Division of Science at the Wits School of

Education has adopted TSPCK as a scaffolding framework to guide their teaching of methodology courses.

In Tübingen, two aspects—the abstraction cone of learning (Lalley & Miller, 2017) and the biologically relevant working methods (Gropengießer et al., 2016, 2018)—are an important part of the lecture "Fachdidaktik". Parallel to the WSoE, the cone of learning is concerned with representations in the widest sense (including original objects), and can be integrated into the TSPCK as part of "Representations". Similarly, the biologically relevant teaching methods overlap in their basic idea with the "conceptual teaching strategies". Thus, the two schools have overlapping basic teaching content. With regard to the TüSE, Gropengießer et al. (2018) is a general textbook on biology education written in German and in use since the 1980s. This means that many cohorts of prospective teachers have read the book and been instructed along the lines of the publication. There are other books concerned with biology teaching, but this is the most widespread book and has the most editions, being updated every five years. Another benefit is that the textbook is written by German experts, therefore many authors contribute to the book, and every chapter is usually written by one or two renowned German biology teacher educators. This distinguishes the textbook from all others that have been written by a small team of two or three authors. The book is additionally used in both phases of teacher education, in the university phase and in secondary teacher education at schools. In this chapter, we have drawn on two important aspects from the contents of the book: the cone of learning and the biologically relevant teaching methods. Figure 1 below shows the cone of learning (adapted from Gropengießer et al., 2018, based on Lalley & Miller, 2007, though with a different methodology).

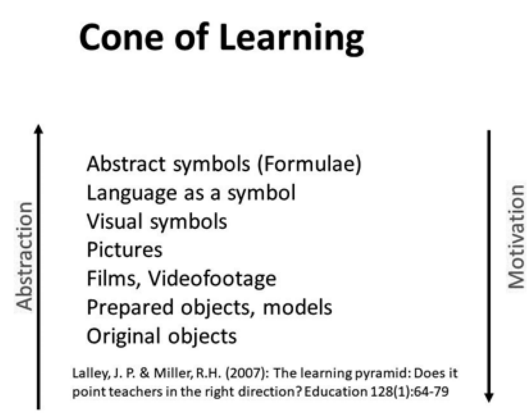

Figure 1 Cone of learning

The cone of learning is about the representations that can be used in biology teaching and learning. This overview arranges modes of representations according to their motivational effect on learners and visualizes the relationship between motivation and abstraction. These representations can be grouped along two continua. The first continuum is related to the abstraction level of the representation. Based on education studies, the argument is that less abstract representations foster learning success and motivation (see Chatterjee et al., 2015; Hummel & Randler, 2012; Novak & Schwan, 2021). For example, Hummel and Randler (2012) and Wilde, Hußmann, Lorenzen, Meyer and Randler (2012) showed that teaching about mice is more motivating and generates higher learning success when living animals are used instead of videos. Of course, there are numerous exceptions to this rule. For example, human biology cannot be taught with original objects and requires non-human animal organs or 3D models as media.

Following this continuum, there is an increasing abstraction from originals, which have the lowest or no abstraction level, followed by modified or prepared originals and objects that are three-dimensional representations, such as models (e.g., of organs like the heart). On the next level, two-dimensional representations follow, beginning with video footage. This is because they are two-dimensional but contain some kind of temporal structure, such as processes, so it is possible to follow a process, like the beating of the heart, on video. On the next abstraction level are pictures that are two-dimensional but lack the process component. Thus, using only an image of the heart while the function is described with a text is less motivating and more abstract. Furthermore, symbols like pictograms follow, as they are two-dimensional but do not show the original pictures and have reduced information content. In this case, one could use simplified images of hearts, which show only the four parts (the atria and ventricles) without any details. Amongst the most abstract representation are language, and symbols such as structural formulae or chemical formulae.

The cone of learning shows that when abstraction levels increase, the motivation of students decreases. To illustrate this, I will use the following example. When teaching the structure and internal organs of vertebrate fish, the original object would be the best choice, from Gropengießer et al.'s theoretical background. Therefore, using a real fish obtained from a butcher for teaching has the lowest level of abstraction; it is real and original, so it is considered to be the most motivating object. On the next abstraction level, the model of a fish would be the second choice, followed by a video showing the dissection and the organs, then by images only, and then by written text. In this respect, biology teaching should always search for the least abstract and most motivating representations. However, this does not only have to do with motivational aspects, as higher motivation relates to higher cognitive gain (Randler, 2009). Nevertheless, the focus is mainly on motivation. In this study, an effective lesson was viewed as one in which the representations were least abstract. This is taught as one of the basics in the lecture "Fachdidaktik", which informs teaching students' decisions in lesson planning.

3 Relating the cone of learning (Tübingen) to the TSPCK framework (Wits)

Comparing the concept of the cone of learning to the TSPCK framework used at the WSoE, some links as well as some disconnections become apparent. One link is that the cone of learning's focus is on representations, which is one aspect or component of the TSPCK framework that a teaching student must consider when planning. However, with the cone of learning, the focus is on the relationship between abstract and concrete representations, whereas in the TSPCK framework, the initial focus is on the nature of the concept to be taught and the teaching students' intentions. Therefore, in WSoE Biology Education classes, questions called prompts (Loughran, Mulhall & Berry, 2004) are used to guide the teaching students to understand the nature of the concept to be taught, so that they can then use that understanding to choose appropriate representations. Examples of such prompts are:

1. What do you intend learners to learn about this idea?
2. Why is it important for learners to know this?
3. Difficulties / limitations connected with teaching this idea.
4. Knowledge about learners' thinking which influences your teaching of this idea.

The fourth point is also taught in Tübingen, but usually in the education classes, and is related to Klafki's questions for didactical analyses. Klafki developed seven basic questions with some additional subquestions. Four of these didactical questions are summarized here: 1) which larger topic does this topic represent; 2) how can children and young people relate to this topic; 3) what is the topic's importance for the future; and 4) what is the inherent structure of the topic (Klafki, 1980)? Below, an example that was used in the previous paragraph and the first three prompts were used to illustrate how the prompts help the teaching student sharpen the focus of the lesson and determine appropriate representations. Referring to the first prompt, if the intention is for learners to learn the concept of fishes' internal organs, then the dissected fish is the most appropriate representation. However, if the intention is to teach about the fish's habitat and behavior, a real fish will not be the most appropriate choice of representation. After this, looking at prompt three—difficulties associated with teaching a particular concept—when teaching about the heart, one of the difficulties is that learners find it difficult to see heart valves and sometimes also atria in a real heart that has been dissected. In such a case, a model may be a better representation for helping learners understand the heart's structure. Therefore, while a real heart could, according to the cone of the learning, be the most motivating representation, it may not be the best choice for a teaching student who is using the TSPCK framework and the associated prompts.

3.1 Biologically relevant teaching methods

The other concept used in the lecture "Fachdidaktik" is that of biologically relevant teaching methods. It focuses on the competencies that biology teachers need to help learners develop. Table 1 below (adapted from Gropengießer et al., 2018) summarizes these competencies.

Competence	**Example**
Fostering competencies, e.g., process-related competencies	Using a microscope, dissections, observations
Experimental competencies (sometimes also labelled "scientific reasoning" or "scientific inquiry")	Planning experiments, explicating hypotheses, collecting data
Model competencies, use of models	Evaluate existing models, improve or develop own models
Gaining knowledge of biological processes	Observing, comparing, experimenting, using models, applying working techniques, microscoping
Working with living organisms	Observe in nature, make non-invasive experiments

Table 1 An overview of the competencies that the biologically relevant teaching methods must develop in learners

The biologically relevant methods are not based on a hierarchy, because all the methods depicted in Table 1 are biologically relevant methods, some of them explicitly mentioned in the governmental curricula. These methods include competencies involved in scientific (biological) processes, such as carrying out experiments and using models. These aspects are usually considered to be on a higher level of the cognitive hierarchy than more practical working methods (KMK BW, 2016). However, these are also important concerns: observing animals/plants, comparing different materials, and applying working techniques such as microscoping. Using living organisms for teaching is also an important method, which overlaps with the cone of learning, where originals are the most motivating and least abstract representation. With regard to these teaching methods, students should include biologically relevant teaching methods in their lesson plans and carry them out in a practical manner. Using the fish example above, this would mean that students themselves should dissect a fish to learn the internal structure. In this case, dissection is a relevant biological method (Randler et al., 2012). Similarly, doing experiments on their own is rated higher than merely seeing a picture of an experiment and reading about the method (Randler & Hulde, 2007). Looking through a microscope is more practical and rated higher than just looking at microscopic images. Because of this, students have to explain in their lesson plans why they have chosen a specific method over another, or why they do not use any specific method. For example, when teaching about climate change, practical work is sometimes impossible, and when teaching evolution, students cannot observe millions of years of evolution during their lessons. In this case, they would have to argue for the method they think is most adequate, e.g., a simulation game for the topic of evolution. In this study, an effective lesson plan was considered to be one with methods that would actively involve learners in the teaching and learning process by using less abstract representations.

3.2 Relating the 'biologically relevant teaching methods' (Tübingen) to the TSPCK framework (Wits)

When the concept of biologically relevant methods is compared with the TSPCK framework, similarities with the component *conceptual teaching strategies* become apparent. The description of biologically relevant methods shows that if applied appropriately, methods that engage students and develop expected competencies can be selected. While the TüSE approach expects students to provide reasons for the choice of methods chosen in the lesson plans, it does not provide scaffolds or reasoning tools to support the development of that reasoning. At the WSoE, it was this shortfall in the methods that motivated the adoption of the TSPCK framework. The component *conceptual teaching strategies* in the framework scaffolds the students' thinking and reasoning by prompting them to consider the other four components, i.e., *learner prior knowledge including misconceptions, curricular saliency, difficulties associated with the teaching and learning of the concept* and *representations,* in deciding the strategies for teaching a particular concept. Considering these four components encourages teaching methods to be chosen that are relevant for the teaching of a particular concept to a particular group of students.

3.3 Research design

At the WSoE in general, but more specifically in the teaching of biology methods courses, the teaching of methods courses to pre-service teachers (referred to in this study as teaching students) training to be biology teachers is informed by the Topic Specific Pedagogical Content Knowledge Framework (Mavhunga & Rollnick, 2013) in order to support teaching students' ability to plan effective lesson plans. In Tübingen, there is no specific framework that guides the teaching of teaching methods. As indicated earlier, teaching students learn to teach based mainly on two key concepts: the cone of learning (Lalley & Miller, 2017) and the biologically relevant teaching methods (Gropengießer et al., 2016, 2018). The scaffolding component is achieved by giving general explanations for lesson planning in the introductory lecture "Fachdidaktik", a mandatory lecture (see next section for details) that is presented throughout the semester. The scaffolding component combines theoretical approaches with empirical support from evidence-based research, then providing best practice examples of biology lessons.

4 Description of the Tübingen introductory lecture "Teaching Biology (Fachdidaktik)"

Fachdidaktik is a mandatory general lecture about teaching biology. The German Fachdidaktik approach has a strong theoretical basis. In Fachdidaktik classes, teaching methods and methodologies are discussed and developed, based on theoretical and empirical research. The basic Fachdidaktik lecture is therefore theory-based in its content, but also includes empirical studies about biology teaching and, lastly, best practice examples that demonstrate the combination of all three aspects. In this lecture, the basic principles are laid out. The theory part of the lecture comprises some kind of axiom, e.g., the way that biology, because of the definition of "bios" (life), should be considered with living objects. From an evidence-based or research-based viewpoint, studies are presented that examine the aspect of living organisms in teaching, their influence on (cognitive) learning success, on motivation, and on emotions such as interest in biology. Furthermore, best practice examples of lessons dealing with living organisms are presented. The main focus is to clearly show how theory informs teaching. Empirical studies are needed to test the theoretical perspective and how it can be taught in an everyday classroom. During the following course of studies, students enroll in a second course (biology lessons planning), where the main aim is to develop a teaching sequence, usually for about 90 minutes. This teaching sequence should be informed by the knowledge gained in the previous lecture. The students have to develop a lesson plan based on the key findings of the lecture "Fachdidaktik". The students not only present the lesson plan, but also incorporate some microteachings, where they make use of the other students as school students. They deliver their lesson plans in part as "real" lessons. This is an important topic, as students often claim that biology is a rather disparate subject without connections to other subjects, such as genetics, botany, evolution, microbiology and molecular biology. Therefore, a curriculum was developed where one step is related to the next. Although we have never tested it, we assume a higher motivation and cognitive learning success when these two parts are interrelated.

5 Lesson plan sampling

During the winter term 2019 / 2020, sixteen TüSE lesson plans were collected, in which the topics were based on the curriculum of the federal state of Baden-Württemberg (MKS). The specific topics covered in the lesson plans were ecology, evolution, and biodiversity. Two parallel courses taught by two different university teachers were studied. The students had to plan real lessons that should be teachable at regular schools and have a length of 90 minutes. They were advised to follow the instructions given in the lecture "Fachdidaktik", which they had to finish prior to the lesson plan course. They were told that they should i) reason about the representations (abstraction, motivation), and ii) consider including real biological working methods in their lesson plans. The lesson plans contain a section dedicated to representations, in which the students write down the representations they would use for each topic. Another column contained the activity of the students, like reading, discussing, or carrying out an experiment.

6 Lesson plan analysis

Qualitative documentary analysis was applied (mainly based on Mayring, 2019) with respect to the aspects mentioned in the cone of learning (Figure 1) and the biologically relevant working methods and competencies. Aspects of the cone of learning and the biologically relevant methods could be extracted directly from the lesson plans, as these plans contain the respective columns. For example, students write "pupils watching a video", so the representation video is extracted. Concerning the biologically relevant teaching methods, students write, for example, "pupils doing experiments themselves", so this was also easy to extract from the lesson plans.

The detailed analysis therefore involved identifying the representations that were planned for. The choice of representations was then compared with a possible "gold standard". This gold standard refers to the choice of the optimal representation, meaning a representation that is likely, according to the cone of learning, to promote higher learner motivation. For example, if introduction to ecosystems was taught, the gold standard would be the use of the real ecosystem. If it is not used, the next level would be the models, followed by the videos. Because of this, the students' choice of representation was checked with reference to the cone of learning. The questions that guided the analysis included: what is the concept that was planned for? What is the ideal teaching method for this concept in terms of learner motivation for the particular concepts chosen by the students? What was possible in the same situation in the same place? If it were possible to leave the classroom within a few minutes and enter an ecosystem, then this would be labelled the gold standard that the student should have chosen under the circumstances.

Similarly, the biologically relevant teaching and learning methods have been compared to the ones that were possible, also at the same date and location. For example, when a textbook included an experiment that could have been carried out by the students themselves, it was also seen as non-optimal teaching. A classification into low, medium and high was used to represent the extent of the manifestation of both the representation's abstraction and the biologically relevant teaching methods. With regard to abstraction, a low level was rated best (e.g., an original object, like the fish), and a high level of abstraction was rated worst. As for the teaching methods, good teaching methods (e.g., use of dissection, experiment, and observation) were rated as high, while teaching methods considered poor (e.g., reading a textbook and making notes) were rated as low.

7 Results

Table 2 shows the analysis results of the sixteen lesson plans that were developed for the teaching of ecology and evolution. As described in the previous section, the abstractness of the representations that were chosen by the students was classified as high, medium or low, with low abstraction levels being rated as more motivating. Biologically relevant teaching methods were rated as high, medium or low, with high meaning greater relevance. Alternative representations are examples of more appropriate representations that could have been used under the circumstances, while alternative methods are concerned with better teaching methods.

Table 2 shows that thirty-two representations were identified across the sixteen lesson plans. Below, we discuss the representations' levels of abstraction and the relevance of teaching methods that were chosen by teaching students, as revealed in the lesson plans.

Student	**Topic**	**Identified representation in students' lesson plans**	**Classification of representation's abstraction**	**Classification of teaching methods' relevance**	**Possible alternative representation**	**Alternative method for biologically relevant methods / work**
1	Biotope & ecosystems	Film clip about different ecosystems	Medium	Medium	Real ecosystem outside	Make real environmental measurements
		Paperwork about different ecosystem	High	Low		
		Planting a “bottle garden”	Low	High		
2	Ecosystems	Picture, paperwork, text	High	Low	Real ecosystem outside	Make real environmental measurements
3	Bergmann's rule	Pictures	Medium	Low		No alternative needed
		Experiments with water of different temperatures and volumes	Low	High		
4	Bergmann's rule	Cooking differently sized potatoes, using thermometers	Low	High		No alternative needed
5	Food chain & food web	Pictures of species	Medium	Medium	Original objects, three animal examples	
		Food chains with text	High	Low		
		Simulation (computer)	Medium	High		

6	Food chain & food web	Pictures	Medium	Medium	Original objects, three animal examples	
		Real food chain (pictures and using a string)	Low	Medium		
7	Biotic factors	Pictures of animals	Medium	Medium		
		Paperwork	High	Low	Real ecosystems	Real measurements
		Game / play-like activity	Low	Medium		
8	Abiotic factors	Compare different biotopes outside, measure environmental variables	Low	High		
9	Carbon cycle	Fridays for Future	Low	Medium	Video simulation	
		Puzzle / paperwork	Medium	Low		
10	Carbon cycle	Real charcoal	Low	–	No alternative	
		Video	Medium	Medium		
11	Adaptations of Vertebrates	Pictures	Medium	Medium	Comparison of real skeletons	
		Paperwork	High	Low		
12	Adaptations of Vertebrates	Pictures, Paperwork	Medium	Low		
13	Darwin's theory	Simulation of selection	Medium	High		
		Pictures, paperwork	High	Low		
14	Darwin's theory	Pictures	Medium	Medium		
		Play-like activity / Simulation	Medium	High		
15	Evidence for evolution	Paperwork Jigsaw method	High	Low		
16	Predator-prey-relationships	Pictures	Medium	Medium	Simulation	
		Paperwork	High	Low		
		Skulls of prey and predator (teeth)	Low	High		
		Graphics / Population dynamics	High	High		

Table 2 Results of the analysis of the 16 lesson plans from Tübingen in the context of teaching evolution and ecology

7.1 Chosen representations' levels of abstraction

Classification of abstraction	Frequency of levels of abstraction
High	9
Medium	14
Low	9

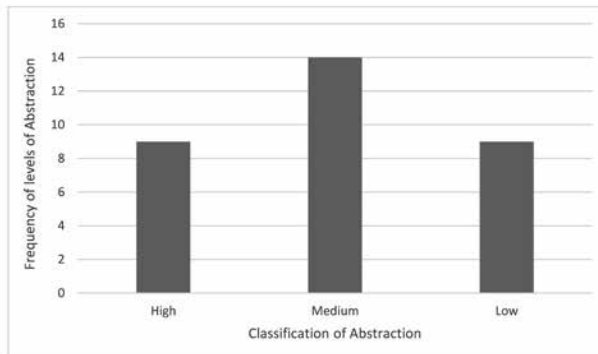

Figure 2 A graphical representation of the representations' abstraction levels, which manifested across all teacher students' lesson plans

All in all, Table 2 shows that nine out of the thirty-two representations were in the form of paperwork. Of these nine representations, six were used in conjunction with pictures and with original representations and graphics. Paperwork and graphics fall under high abstraction, pictures fall under medium abstraction, and real objects fall under low abstraction. In addition to the six pictures that were used with paperwork, pictures were also used in three other lesson plans (in conjunction with text, an experiment and a simulation). Figure 2 is a graphical representation of the abstraction levels, of the representations which were indicated across all teacher students' lesson plans. Because more than one representation was used in some lessons, the total number exceeds N=16.

Figure 2 shows that nine out of the thirty-two representations were at a high abstraction level, fourteen were at a medium level and nine were at a low level. Nine out of the thirty-two teaching methods identified in nine of the sixteen lessons contained highly relevant methods, such as experiments carried out by the students themselves. Eleven methods were at a medium level while eleven were at a low level, such as reading text and extracting it into a working sheet. Figure 3 below shows three classifications concerning the manifestation of biologically relevant working methods. As with the abstraction levels, because in some lessons more than one method was used, the total number exceeds N=16.

7.2 Comparison of the chosen representations with the gold standards

As explained earlier, the gold standard refers to the choice of the optimal representation, optimal meaning a representation that is likely to promote higher learner motivation according to the cone of learning. The teaching students' lesson plans were based on two broad biology topics, namely ecology and evolution. These topics are used as sub-headings in this section to highlight the quality of students' chosen representations and teaching methods.

Classification of biologically relevant work	Frequency of levels of biologically relevant work
unclassified	1
High	9
Medium	11
Low	11

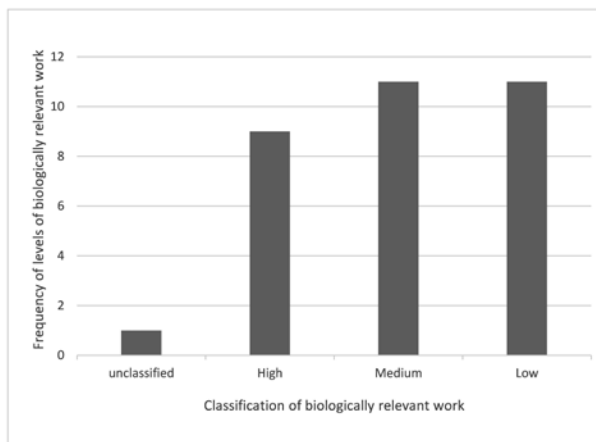

Figure 3 Classification of the manifestation of biologically relevant working methods in the 16 lesson plans

7.2.1 Topic: ecology

Students 1 to 10 planned to teach topics on ecology. The topics that were planned for are ecosystems, Bergmann's rule, food chains and webs, biotic factors and the carbon cycle. Lesson plans #1 and #2 were on ecosystems. In these two lessons, one student used a video / film clip which provided medium-level abstraction, but used it in combination with the real objects. This lowered the abstraction level for some aspects of the lesson. Both students used paperwork, which is a plausible alternative in teaching these topics. However, a real ecosystem would be the optimal representation, as the location of the course is near a botanical garden. Getting students to take measurements in a real ecosystem would therefore be a relevant teaching method. When teaching ecosystems, students could just leave the classroom and compare different micro-ecosystems that are reachable on foot within a few minutes.

Lesson plans #3 and #4 were concerned with Bergmann's rule, which is usually illustrated by different penguin species: smaller penguins live near the equator and larger ones near the South Pole (Meiri & Dayan, 2003). Here, one student used pictures to portray the problem of body size versus latitudinal gradient, which is of medium abstraction. However, each student chose a different experimental / observational approach. Both approaches were concerned with larger bodies cooling down at a slower rate than smaller ones. However, one group used potatoes of different sizes, while the other used water beakers of different sizes. Students then had to measure temperature changes over a given period of time. In these two lessons, therefore, the level of abstraction was low and the teaching methods were biologically relevant.

Lesson plans #5 and #6 were on the topic of food chains and food webs. Student 5 used text, pictures of food chains and webs, and a computer simulation as representations, while student 6 used pictures of organisms and asked students to construct food chains using pictures and string. Most of the representations were of medium abstraction and the methods of teaching were biologically relevant. For lesson plan #7, as with lesson plans #1 and #2, the choice of representations was paperwork with books, texts, and pictures about different ecosystems. Students had to compare the biotic and abiotic factors of ecosystems and construct a table at the end of the lesson. This is from the very abstract representation level (teach ecology from paper), and also from the biologically relevant teaching methods. Paperwork is rated the lowest because it is not tied directly to biological methods. This can be directly contrasted with lesson plan #8, where students left the classroom to take some biotic / abiotic measurements in front of the classroom, e.g., by going out and comparing a small fragment of wood versus a meadow, focusing on measures like differences in ambient temperature, hygro, lux and wind speed between the locations. According to the cone of learning, the motivation is high because students encounter a real ecosystem, not a representation, while the other lesson plans used language, symbols and pictures. Furthermore, taking real measurements is a biological method, fitting the requests made by Gropengießer et al. (2018, Table 1). It is therefore rated much higher in terms of both abstraction of representation and biologically relevant teaching methods. These examples show that such teaching is possible and can be implemented into everyday lessons. In lesson plans #9 and #10, which were on the carbon cycle, representations at a low and medium level of abstraction were chosen by the teaching students.

7.2.2 Topic: evolution

Lesson plans #11 to #16 were based on different aspects of evolution, namely animal adaptations, Darwin, evidence for evolution and predator-prey relationships. Since the topic of evolution is abstract by nature, most of the representations used were of high and medium abstraction. However, for some of the aspects, there were alternative representations that teaching students could use. For example, with lesson plans #11 and #12, which dealt with adaptations of vertebrate species, different classes of vertebrates (e.g., fish, amphibians, reptiles, birds, and mammals) were compared by using different pictures, e.g., of their skeletons. However, a better alternative to the cone of learning would have been to use real skeletons and stuffed animals or models for the comparison, e.g., of the limbs. This would have been less abstract and more motivating. Also, comparing is an essential biological research method that can, of course, also be done with pictures on working sheets. However, motivationally speaking, it might be better to use models or real objects.

7.3 Discussion

The purpose of this study was to investigate the cone of learning and the biologically relevant methods as scaffolding tools for developing teaching students' capacity to prepare effective lesson plans. The questions that guided this study were:

1. How do the concepts of the cone of learning and biologically relevant methods used at Tübingen Biology Education Department support the scaffolding of lesson planning?
2. How do the concepts of the cone of learning and biologically relevant methods used in Tübingen relate to the TSPCK framework that is used at WSoE?

The results of this study showed that a representation was used in each of the sixteen Tübingen students' lesson plans to facilitate learning. However, pictures and paperwork, which fall under medium abstraction, were the most used representations, despite the availability of more motivating and less abstract alternatives. In their lesson plans, teaching students seemed to have ignored or failed to apply the aspects of lesson planning that they were taught in the general lecture about biology teaching. For example, about half of the students ignored one of the main questions that they needed to respond to in their planning: "What did you carry out as a biological method during your lesson?", and secondly: "Did you consider the abstraction level of the representation by focusing primarily on the most original and least abstract object?" As seen in Table 2, there were plenty of alternative and better representations that students could have used.

8 Relating Tübingen students' lesson planning to the lesson planning approach used at WSoE

The analysis and discussion above shows that Tübingen students' lesson plans included at least one representation and an attempt to engage students in biologically relevant methods. What was missing in the lesson plans was students' reasoning for the choice of the representations and of the biologically relevant methods. Therefore, while the representation may appear to be less abstract, a teaching student's reasoning and intention for the lesson could be aligned with that particular representation and biological method. As mentioned in an earlier viewpoint, aspects such as the intention of the teacher, or the nature of the concept being taught and learner prior knowledge can influence the choice of representation and the biologically relevant method used in a particular lesson. There is therefore a need to devise ways of capturing teaching students' reasoning for the choices they make as reflected in their lesson plans. At the WSoE, the TSPCK-aligned lesson plan templates have prompts that provide teaching students with opportunities to verbalize their thinking and reasoning as they plan. In this way, teacher educators can assess the teaching students' reasoning and the appropriateness of the representations and conceptual teaching strategies that are chosen.

9 Limitations of the study

Only one source of data, teaching students' lesson plans, was used in this study. Being a qualitative study, multiple data sources would have improved the validity of the results. Another data source could be the interviews of the teaching students. In this study, the authors had plans to interview students in order to acquire more insight into their planning from their pedagogical reasoning. However, due to restrictions imposed because of the COVID-19 pandemic, the interviews could not be carried out.

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