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Perspective-Based Generic Questions as a Tool to Promote Student Biology Teacher Questioning

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Abstract
In biological research, generic questions that are derived from perspectives (ways of looking at and thinking about life processes) help in generating specific questions. In this study, we used perspective-based generic questions as scaffolds to support student teachers in increasing the quality and quantity of their questions about biological topics. Fifteen student biology teachers were given an intervention to individually generate, in 15 min, as many questions as possible that they might ask in class about standards from the national syllabus for biology on a particular biological topic, first without using, and then using a set of perspective-based generic questions. The results of this study show that, using perspective-based generic questions, student teachers generated significantly more and higher quality questions. The formulated questions can be applied in two different contexts: during practicum, when student teachers actually teach biology, or when they plan future lessons, as the basis of challenging tasks or assignments, with the aim of getting students interested in finding the answers.

Keywords Perspectives · Teacher questioning · Scaffolding · Student teachers · Biology education

Introduction

Teachers often experience difficulties in asking higher order questions in class and tend to pose shallow rather than deep questions and short-answer rather than long-answer questions (Chin 2007; Dillon 1988). Student science teachers experience even more difficulties in asking questions. Although generating and answering questions have positive effects on comprehension and thinking by students, the number of questions asked by student teachers during practicum is low, and the quality of these questions is poor (Ahtee et al. 2011; Eshach et al. 2013).

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Perhaps the clearest distinction between lower and higher order questions is that while lower order questions are designed to elicit existing answers (e.g., from the textbook, directly from the lecture) (Renaud and Murray 2007), higher order questions are those which stimulate learners to think more deeply, e.g., application, analysis, or evaluation of information (Ayaduray and Jacobs 1997). When teachers pose higher order questions, they aim to trigger the process of productive thinking in students (Chin 2007). Productive thinking elicits students' thoughts, encourages them to elaborate on their previous answers and ideas, and helps them construct conceptual knowledge. Higher order questions are also used to diagnose and extend students' ideas and to scaffold students' thinking (Chin 2006). Therefore, it is crucial that teachers pose higher order questions so that students have the best opportunity to acquire the necessary productive thinking skills.

In the current study, we introduce a questioning tool with the aim to increase the quality and quantity of questions generated by student biology teachers. We first discuss the nature and necessity of question scaffolds according to Rosenshine et al. (1996). We then introduce a tool that could scaffold student biology teacher questioning and discuss the tool's relation to biology education. Next, we describe the design and results of a study on the effects of the questioning tool on the quantity and quality of questions generated by a cohort of 15 student biology teachers. We conclude with some implications for the use of the questioning tool in biology classrooms and in biology teacher education.

How to Scaffold Teacher Questioning

In many studies, the importance of teacher questioning and that teachers usually have difficulty with this is underlined. There is hardly any research that focuses on interventions to promote questioning of higher order questions by teachers. If this is the case, the focus of the research is on how teachers should deal with questions (Chin 2007) and not how to formulate them themselves. However, there is literature on how to scaffold student questioning from which we try to derive lessons to formulate higher order questions. To help students learn less-structured tasks, scaffolds can be provided. Scaffolds are temporary supports, which serve as aids during the initial learning of a complex skill or cognitive strategy and are gradually removed as the learner becomes more proficient (Rosenshine et al. 1996). In the context of promoting questioning, procedural prompts are often used. Procedural prompts (Scardamalia and Bereiter 1985) are a type of scaffold, which supply the students with specific procedures or suggestions that facilitate the completion of the task. Learners can temporarily rely on these hints and suggestions until they create their own internal structures (Scardamalia and Bereiter 1985).

In a subsequent review, Rosenshine et al. (1996) distinguished five types of procedural prompts that could help students learn how to generate questions. The first type of procedural prompt to scaffold questioning was the use of signal words. Hereby, the question always started with a signal word like who, what, where, when, and why. Students are taught how to use these words as prompts for generating questions. The second type of procedural prompt was generic question stems and generic questions. This scaffold is based on some generic questions or stems of generic questions which you can always use. The difference between generic questions stems and generic questions is based on the type of questions provided. Examples of generic question stems are "How are … and … alike?" and "What is a new example of …?" Generic questions are given in full and do not need to be completed, for example, "What are the key words? Do I know what they all mean?" and "What is the main

idea of this passage or chapter?" The third procedural prompt was called the main idea. Students first had to identify the main idea of the paragraph, and thereafter, questions should be generated. According to Rosenshine et al. (1996), this was less effective, which could be caused by the fact that developing the main idea of a passage is a difficult cognitive task. The fourth procedural prompt was based on question types (Raphael and Pearson 1985). All questions were divided into three types, each based on the relationship of the question with the answer. The three types of questions were as follows: Can the answer of the questions be found in one sentence, is the answer to be found in two or more sentences, "or is the answer not all in the text?" This question type prompt was not effective for learning to ask questions, due to the fact that students learned to identify and recognize types of questions. The last procedural prompt to scaffold questioning was the use of story grammar categories. In this case, students were taught to use a story grammar to help understand a passage of a text they were reading. Students had to focus on four elements of a text (the setting, the main character, the main characters goal, and the obstacles encountered by the main character) and ask questions that focused on each element.

Research shows that of the five variants of procedural prompts, generic questions and generic question stems have the largest effect sizes (Joseph et al. 2016; Rosenshine et al. 1996). These generic questions provide specific procedures, suggestions, and tools that can help in generating deeper and more specific questions. In comparison with other procedural prompts, they provide more direction and are easier to teach and apply. Even more effective than generic questions are domain-specific generic questions, and these questions contain information about the domain in question. In our study, we focus on domain-specific generic questions as a tool to scaffold student biology teacher's questioning. These domain-specific generic questions are a combination of a complementary and effective scaffold with generic and domain-specific characteristics. Devolder et al. (2012) found that prompts seemed to be more effective when used in combination with others. The content of prompts is often determined by the need to provide students with either domain-specific or generic information. Literature states that generic prompts are limited in their success to fostering knowledge integration when used individually (Bulu and Pedersen 2010). The prompts that are individually ineffective are generic, whereas the complementary and effective scaffolds are both generic and domain-specific (Devolder et al. 2012).

To scaffold student biology teachers' questioning, therefore, we searched for domain-specific generic questions for biological topics. Inspiration for domain-specific generic questions is based on insights about how scientists ask questions about new objects of research (Hintikka 2007; Rescher 2001; Thagard 2012; Wimsatt 2007). Two mechanisms for generating questions can be distinguished. First, new questions arise primarily in answering previous questions. Researching a question almost always results in new questions. As Popper (1973) noted, science starts and ends with questions. Generating questions through this mechanism already requires in-depth knowledge of the subject matter because you can only formulate more precisely what you do not know, resulting in the follow-up question (Rescher 2001). In addition, this way of asking questions suggests that you have a starting question that you can begin with (Hintikka 2007). The second mechanism for generating questions does not require detailed knowledge, and it is just about generating first questions for a fresh line of research. Where do such questions come from? These initial questions arise from general ideas about the object of research (Kuipers 2007). These general ideas are also called perspectives (Giere 2010; Callebaut 2012; Wimsatt 2007). A perspective is a way of looking and thinking. Take for example the issue of the plastic soup. This issue can be viewed from multiple disciplinary

perspectives. With each perspective, other aspects are highlighted and other questions become relevant. From a communicative perspective, for example, the question why this phenomenon is indicated by the term plastic soup can be asked and which effects this has in the communication. From a physical geographic perspective, for example, the question where the plastic soup is located in the ocean can be asked and why right there? From an ecological perspective, the central question, among other things, is what the consequences of this pollution are for preventing and spreading species. An ethical perspective raises the question of what we should do with the plastic soup and who the stakeholders are, etcetera.

For our purposes, perspectives seem the most suitable candidate for formulating domain-specific generic questions because this does not require highly detailed knowledge to come up with new questions and can also help to formulate the first start question.

To summarize, to scaffold student biology teachers' questioning, we propose providing domain-specific generic questions to student teachers when formulating questions. In order to develop such domain-specific generic questions, we must first identify which perspectives biologists use and which of these are suitable for biology education and derive domain-specific generic questions from these perspectives. These domain-specific generic questions function as a scaffold to promote student teacher's questioning about biological topics.

Perspectives Biologists Use

Biology studies life in all its diversity and at different organizational levels: from molecules to biosphere. In the 1960s, there were two leading biologists, Ernst Mayr and Nico Tinbergen, who independently tried to structure the diversity of subdisciplines that characterize biology (Mayr 1961; Tinbergen 1963). They did this by distinguishing a number of guiding questions that a biologist can ask when studying life phenomena. These guiding questions were in turn based on perspectives. More than 50 years later, their complementary proposals are still regarded as very valuable and directive for the investigation of life phenomena (Bateson and Laland 2013; Burkhardt Jr 2014; Nesse 2013). We will briefly discuss both proposals below, starting with Mayr's original proposal because Tinbergen's proposal can be regarded as a refinement of Mayr's questions.

The evolutionary biologist Ernst Mayr presented in his paper *Cause and Effect in Biology* (1961) a simple, but influential dichotomy for questions in biology. He made a distinction between how questions that relate to proximate causes and why questions that relate to ultimate causes. He illustrated this on the basis of biologists who wanted to investigate migratory behavior of a particular bird species. They can ask the question how this works. They then search for genetic, physiological, or ecological causes of the migratory behavior. But they can also ask why a particular bird species migrates. This concerns questions about the selective advantage of migration behavior and/or how migration behavior has evolved. Mayr emphasized that for a full understanding of a life phenomenon, both types of questions must be asked and answered.

The prominent ethologist Niko Tinbergen presented in 1963 a proposal for a set of guiding questions for biology in general and ethology (behavioral theory) in particular. He distinguished the following four questions: "How does it work?," "How is it developed?," "What is it for?," and "How did it evolve?." Take, for example, the singing of a robin. If we want to understand this phenomenon well, we must view it from all four perspectives, according to Tinbergen. We can wonder how the robin produces vocals (mechanistic perspective: "How does it work?"). But also how the singing of a robin develops during life (developmental perspective: "How is it developed?"). We can also investigate what singing is actually for

(functional perspective: "What is it for?") and how singing has evolved (evolutionary perspective: "How has it evolved?"). Nesse (2013) considers Tinbergen's four questions as a refinement of the division of Mayr. Demand for the proximate cause of Mayr is split up by Tinbergen into questions about its operation and development. Mayr's question about the ultimate cause differentiates with Tinbergen from a question about the function (selective advantage) and a question about the evolutionary reconstruction of the trait.

Forty years later, Mayr has in his influential *This is biology: The science of the living world* (1997) explicitly added three guiding questions that were implicit in his earlier work and that of Tinbergen. First, he adds the taxonomic question: "What is that?" and the accompanying comparative question: "What are the differences and similarities?." Mayr emphasizes that comparative and taxonomic research still plays a very important role in the further development of other subdisciplines of biology. In addition, he reserves a separate chapter on questions that are asked within the field of ecology. This includes the question of what an organism needs in its environment. This concise description of the structure of biology thus yields seven perspectives that biologists—often implicitly—use to formulate questions about virtually every life phenomenon, such as migration behavior or singing of birds. In this study, we examine to what extent these domain-specific generic questions can also support student teachers in developing a broad set of higher order questions for pupils on biological subjects.

Perspectives for Biology Education

The seven perspectives and associated guiding questions just discussed form the core of the set of questions for student teachers. Because biology education must not only be subject relevant but also personal and socially relevant, we have supplemented this set with perspectives that reflect the most important personal and societal applications of biology (Janssen and van Berkel 2015). To explore social and personal relevance of a biological topic, the aforementioned biological perspectives were completed with the medical perspective, the technological perspective, the personal perspective, and the ethical perspective (Janssen and van Berkel 2015).

Janssen and de Hullu (2008) developed 11 perspectives (Table 1) to help teachers generate higher order questions. We derived domain-specific generic questions from these perspectives. For instance, from the functional perspective, we can derive the domain-specific generic question: What is its function? The formulation of domain-specific generic questions is the result of several rounds of a cyclical process of formulation, testing, reflection, and revision (Janssen and de Hullu 2008). Several versions of the domain-specific generic questions have been trialled in the context of several courses for student biology teachers as well as for experienced biology teachers. More than 200 beginning and experienced biology teachers used the perspectives for designing and carrying out lessons in which students think productively about biological phenomena (Janssen, de Boer, Dam, Westbroek and Wieringa 2013). Aside from these trials of all perspectives and domain-specific generic questions together, some perspectives like the mechanical perspective and the environmental perspective were studied separately and published (Janssen, Tigelaar and Verloop 2009, Janssen and Waarlo 2010).

The 11 domain-specific generic questions (Table 1) are meant to be useful for viewing numerous educational biological topics in different ways. To illustrate this, we formulated for each perspective and domain-specific generic question at least one sample question by the subject of the human heart. We expected that the perspectives and domain-specific generic questions would allow teachers to generate higher order questions.

Table 1 Eleven perspectives and accompanying domain-specific generic questions for biology education, illustrated by the subject the human heart

Perspective	Domain-specific generic question	Sample question
1. Taxonomic	What is it?	*Where in the human body can you find the heart?*
2. Comparison	How can it be classified?	*Does the human heart look the same as the heart of a bird or a reptile?*
3. Functional	What is its function?	*What is the function of the atrium and the ventricle?*
4. Mechanical	How does it work?	*How do the heart valves work?*
5. Environmental	What does it need from its environment?	*What does the heart needs in his environment?*
6. Developmental	How is it developed?	*What happens when a baby is born with the functioning of the heart and respiration?*
7. Evolution	How did it evolve?	*How has the heart evolved during the evolution of man?*
8. Medical	What can go wrong and how can it be treated?	*How can you treat a heart attack? Is the brain damaged when the heart stops beating?*
9. Technological	How can you put it to use?	*How can you use the heart? Can you transplant a heart?*
10. Ethical	What are you allowed to do with it?	*What are you allowed to do with the heart? Is it allowed to sell a sheep's heart as food?*
11. Personal	What does it mean to you?	*What does the heart mean to you? Does poetry increase your heart rate?*

To analyze the quality of the generated questions, a questioning hierarchy developed and validated by Taboada and Guthrie (2006) was used. This hierarchy characterizes a wide range of question levels in a qualitative way. Questions are described in terms of their request for information in a way that is clear for multiple users and applicable to various domains (factual versus conceptual questions can be described in for instance biology, geography, and history).

Aim of Study

In this study, the perspectives and accompanying domain-specific generic questions from Table 1 were provided to biology student teachers as a cue card, to assist them while teaching during practicum in formulating higher order questions. However, we did not provide the sample questions, because we wanted to prevent that the student teachers would simply replace the word heart with the topic we choose. In other words, the cue card consisted of the two left columns of Table 1.

An exploratory study was conducted to determine to what extent student teachers' frequency and quality of generating questions increased as a result of using the cue card instead of using no prompt at all. Also, we aimed to determine whether or not the perspectives used when generating questions showed a larger variety when the cue card was used.

The following research questions were addressed:

1. Does the number of generated questions about biological topics increase when student teachers make use of the cue card compared with not using the cue card?

2. Are there more higher order questions formulated when student teachers make use of the cue card compared with not using the cue card?
3. Do the perspectives used while generating questions show a larger variety when student teachers make use of the cue card compared with not using the cue card?

Method

Participants

Fifteen student biology teachers enrolled in this study. This was the entire cohort of student biology teachers following a 1-year post graduate preservice teacher education program (60 European Credit Transfer System credits) in a Dutch university. Fifty percent (30 ECTS) of the program was committed to internships in schools. The methods course (7 ECTS) they followed was a compulsory part of the curriculum of the teacher education program. They had previously obtained a MSc degree in biology. The participants spent 1 day a week at the university and taught an average of seven biology classes in secondary schools on the remaining days. At the time of data collection, the student teachers had approximately 6-months teaching while during practicum experience. They were not familiar with the perspectives.

Procedure and Data Collection

With this study, we wanted to examine to what extent quantity and quality of generated questions by student teachers increase if they use the cue card. Given the explorative nature of the study, we applied a one-group pretest-posttest design (Allen 2017). With the pretest, a baseline for participant performance without cue card could be established. The cue card was then introduced, and student teachers generated questions with the cue card. The final step was to compare the numbers and quality of the generated questions without and with cue card.

During a methods course session, the student teachers were given two different standards from the national syllabus for biology on a particular biological topic; these were similar in difficulty, structure, and length, but had different content (Table 2). The standards are taught in the exam year and are part of the same chapter of the used biology book, showing the relationship between the standards. Chosen topics are common knowledge for the student teachers as the function of the nerves and the muscles is part of their biology study. We chose two different standards because we wanted to avoid that a learning effect would occur after the formulation of questions about the first standard. By using another standard the second time, this was avoided.

Table 2 Standards used for the assignments of the student teachers to generate questions

	Without cue card	With cue card
Standard	*Indicate the function of a nerve cell using the following terms: cell body, myelin sheath, impulse conduction, synapse*	*Indicate the function of muscles and how muscles contract using the following terms: striated muscle, smooth muscle, muscles antagonists*

First, the student teachers were given the assignment to individually generate as many questions as possible that they might ask in class about the first standard, without using the cue card. They had to write these questions on paper, within a time limit of 15 min. The paper was handed in afterwards. Next, the cue card was briefly introduced by their biology educator with an example for each domain-specific generic question with a salamander as an example. It was showed how questions about a salamander could be generated with the help of the cue card. For example, "Is a salamander a reptile or an amphibian?" (comparison) or "In what environment does a salamander live mainly?" (environmental). This was done for all perspectives. This took less than 10 min. After this, each student teacher got his own cue card. They had to write as many questions as possible individually about the second standard on paper, again within a time limit of 15 min. The paper was handed in afterwards. This way, we collected the data on the quantity and quality of the generated questions and the perspectives used without and with the cue card.

The instrument used to determine if the student teachers found the cue card helpful during generating questions about the given standards consisted of only one question asked by the researcher which was "Do you think the cue card is helpful during generating questions and give a brief explanation of your answer?" Student teachers had to write down their answers anonymously on paper and return the paper to the researcher. The question was asked directly after the second assignment and took about 10 min.

Data Analysis

To determine the number of questions generated, the questions composed using and without using the cue card were counted in total and per student teacher. A paired-samples *t* test was conducted to compare the numbers of questions generated per student teacher using and without using the cue card.

To determine the quality of the generated questions, the first author and an independent researcher (both biologists) coded the generated questions per student teacher into one of the four levels of the questioning hierarchy from Taboada and Guthrie (2006), which are described below. This was done separately for both conditions. An interrater reliability analysis using the kappa statistic was performed to determine consistency among raters (Viera and Garrett 2005). The interrater reliability was good (Cohen's $\kappa = 0.67$) with a rater agreement of 77.1%. After several trials, Taboada and Guthrie constructed four levels of questions, starting with level 1.

Level 1 questions are simple in form and require a factual proposition or a yes/no answer, such as "Which function has muscle tissue?"

At level 2, questions request a global statement about a concept or an aspect of an organism, such as "What are the differences and similarities between different types of muscle tissue?"

Level 3 questions are requests for detailed explanations of a specific aspect of a concept with additional evidence, such as "How did the different types of muscle tissue develop and why do these different types exist?" Such questions require specific prior knowledge about a concept that is contained in the question itself.

Questions of the highest level, level 4, are different from the other three levels because they constitute a request for principled understanding, with evidence for complex interactions among multiple concepts. Interactions between two or more concepts are central to the requests for information. For example, "Is it possible to culture muscle and is this cultured muscle meat a substitute for meat produced from conventional sources?"

Taboada and Guthrie (2006) put questions which could not be categorized into level 0. These were religious, rhetorical, or anthropomorphic questions, such as "Why did God make deserts?," "Make assignment a, b and c from your workbook," and "Are animals in the zoo sad?."

In summary, the progression from level 1 to level 4 questions is based on the complexity of the question as expressed in requests for knowledge, with level 1 questions requesting factual knowledge and levels 2 to 4 asking about conceptual knowledge with increasing degrees of specificity and complexity within the question. Therefore, level 2 to 4 questions could be considered as higher order questions, because they aim to help students to construct conceptual knowledge, which as a result may stimulate productive thinking.

We categorized the generated questions into the four levels; however, there were a number of questions that were more difficult to come to an agreement. Two types of questions led to discussion: whether prior knowledge was required to answer the question or not and when a question consisted of two parts of different levels. Both types of questions are discussed below.

With several questions, there was discussion about whether prior knowledge was needed to answer the question or not. Per question of this type, it was determined if prior knowledge was needed to answer the question. This was the case, for example, with the question "What motor skills do you lose when you damage your calf muscle? Can this be taken care of by transplanting other muscle tissue, for example, from the intestine?" This question can be categorized as level 1 because one can answer the question with yes, making it a level 1 question. On the other hand, students need prior knowledge of multiple concepts (transplantation as well as the different types of muscle tissue) in order to answer the question properly, making it a level 4 question. In this case, we decided prior knowledge was needed to answer the question, and therefore, we assigned this question as a level 4 question.

For a number of other questions, there was a difference in categorizing between both raters because the question consisted of two parts, the first part of the question being of a different level than the second part. For each question of this type, the leading level of the question was determined and this level was assigned to that question. For example, with the question "You will see three drawings of different nerve cells. Which is the sensory, motoric or switching neuron and what is the relation between the length of the axon/dendrite and the function of this nerve cell?" The first part is a level 1 question, because it is simple in form and requires a factual proposition (which is the sensory, motoric, or switching neuron) and the second part is a level 2 question because it asks for a global statement about an aspect of an organism (length of the axon/dendrite). The above question was assigned as a level 2 question. Another example of this type of question is;"What is the difference between a muscle cell, a heart cell and a skin cell? Give a drawing with all organelles and indicate the function." The first part of the question is from level 1, because it asks for a factual proposition, and the second part is a level 3 question because a detailed explanation of a specific aspect (organelles of the cell) is asked for. This question was assigned as a level 3 question.

For the questions generated without using the cue card as well for those generated using it, the levels of the questions were expressed in absolute numbers and as a percentage of the total number of questions generated using or without using the cue card. These data are displayed in Table 4.

To categorize the generated questions into the appropriate perspectives, the first author and an independent researcher used the cue card and Table 3 to identify the used perspectives and assigned all questions to the corresponding perspective, because student teachers did not write which perspective they chose per generated question. Questions from level 0 were not classified. An interrater reliability analysis using the kappa statistic was performed to

Table 3 Descriptions of the 11 perspectives and examples of domain-specific generic questions and italic keywords used to assign generated questions into the corresponding perspective

Perspective	Description	Examples of domain-specific generic questions with keywords in italics
1. Taxonomic	Biological systems have characteristics and can be classified on this basis in groups.	Questions that determine what characteristic it is: *What is it?* But also, for example: *What are* the characteristics of a group? Which group does it belong to?
2. Comparison	Biological systems are very diverse and can be compared with each other.	Questions involving two or more biological systems are compared: *How can it be classified?* What are the *differences* and similarities? But also, for example: With what can you compare it? What distinguishes system A from system B?
3. Functional	Biological systems have been adapted to fulfil certain functions for the system of which they are part.	Questions that ask for the function of a property of an organism: *What is the function?* But also, for example: What is it for? What role does it play in the system? What is the disadvantage when it is missing? What is it an adjustment for?
4. Mechanical	Biological systems consist of components and causal relationships between these components that cause the behavior of the system.	Questions about how a biological system works: *How does it work?* But also, for example: How is it caused? How do parts of a system work together? What is the *mechanism*?
5. Environmental	Biological systems need a certain environment to fulfil their functions.	Questions about what is needed to fulfil one or more functions in a certain environment. *What does it need from its environment?* But also, for example: What does it *need* in the area? What happens if the environment changes, or if it is placed in a different environment?
6. Developmental	Biological systems develop during their life cycle in a number of stages.	Questions about the development of a biological system. *How is it developed?* But also, for example: Which stages/stages can be distinguished? How does it change over the course of life?
7. Evolution	Biological systems originated in a gradual evolutionary process.	Questions about how a system has evolved: *How did it evolve?* But also, for example: Which *evolutionary* stages can be distinguished. What are preliminary stages? What is it (originally) selected for?
8. Medical	If biological systems no longer fulfil their functions properly, diseases can sometimes be treated.	Questions about what happens when a biological system is not functioning properly and how this can be treated: *What can go wrong and how can it be treated?* But also, for example: What are the symptoms of disease X. What happens if certain functions are not properly fulfilled? What are the advantages and disadvantages of the *treatment*?
9. Technological	We can change, use, and sometimes produce biological systems for our set goals.	Questions about what we can do with biological systems: *How can you put it to use?* But also, for example: Which requirements must the *design/use* meet? How can it be used? What are the advantages and disadvantages of the design or use?

Table 3 (continued)

Perspective	Description	Examples of domain-specific generic questions with keywords in italics
10. Ethical	Not everything we can do with biological systems is ethical.	Questions about what we can do with biological systems. *What are you allowed to do with it?* But also, for example: What is *ethical*? Who should be taken into account and in what way? What is a righteous or caring relationship?
11. Personal	Biological systems can have a personal meaning for you.	Questions about what a biological system means to the person: *What does it mean to you?* But also, for example: What *feelings* does it evoke in you? What does this mean for your behaviour? What is important to you?

determine consistency among raters (Viera and Garrett 2005). The interrater reliability was good (Cohen's $\kappa = 0.77$) with a rater agreement of 81.3%.

In Table 3, we show a description of each perspective and examples of domain-specific generic questions belonging to a specific perspective. The main question (italicized) comes from the cue card complemented with example questions which contain keywords that we have italicized because they often come back in questions that belong to that certain perspective. For example, the keywords *compare* and *difference* belong to the comparison perspective, whereas the keyword *function* belongs to the functional perspective and the keyword *evolution* belongs to the evolution perspective. Examples of these questions with italic keywords are "What are the *differences* between smooth muscle tissue and striated muscle tissue?" (comparison), "Which *function* has muscle tissue?" (functional), and "What kind of muscle has evolved earlier during *evolution*?" (evolution). To analyze the generated questions into the right perspectives, the first author and the independent researcher have made a list of all the generated questions and categorized them independently. For each question, it was first looked whether this question contained a keyword from Table 3. If this was the case, the question was categorized into that perspective. If this was not the case, it was examined whether the question resembled one of the examples of domain-specific generic questions also from Table 3. The question then was assigned into the corresponding perspective.

Some generated questions were more difficult to categorize because they contained two perspectives at once. If this was the case, both researchers determined what the leading perspective was and categorized the question into this perspective. For example, the question

Table 4 Total number of generated questions per level without using and using the cue card in absolute numbers and percentages

Level	Without cue card		With cue card	
	Absolute	Percentages	Absolute	Percentages
0	7	9.9	6	6.5
1	8	11.3	15	16.1
2	36	50.7	37	39.8
3	19	26.8	27	29.0
4	1	1.4	8	8.6
Total	71	100	93	100

"Multiple sclerosis: what is different from normal?" contained the diagnostic perspective but also the comparison perspective. However, in this case, the question is about what happens when a system does not function in its normal state, which is the case with the disease of multiple sclerosis. We therefore chose to categorize this question as one from the diagnostic perspective. Another example is the question "What are the differences between smooth muscle tissue and striated muscle tissue and explain these differences by describing their function?" This question contains the comparison perspective as well as the functional perspective. The emphasis of this question was on the comparison perspective as it asked twice for differences between certain types of muscles and the function is a way of comparing the types of muscles but that could also be done with another perspective, for example, from the mechanical perspective. We therefore categorized this question as one from the comparison perspective.

For the questions generated without using the cue card as well for those generated using it, the used perspectives were expressed in absolute numbers and as a percentage of the total number of questions generated using or without using the cue card. These data are displayed in Table 5.

To analyze how the student teachers responded to the question about the helpfulness of the cue card, we classified their responses in a positive, neutral, or negative category. Where positive comments contained "yes" or indications that the student teachers found the cue card valuable when designing questions, neutral comments said "yes, however…" or "yes, to some extent." In the case of negative comments, the students formulated disadvantages.

Results

Results Concerning the Number of Generated Questions

Using the cue card while generating questions increased the total number of questions of all student teachers together from 71 for the first standard to 93 for the second standard. There was a significant increase in the average number of questions generated per student teacher: without using the cue card ($M = 4.7$, SD = 2.9) and using the cue card ($M = 6.2$, SD = 2.5), $t(14) = -3.556$, $p = 0.002$.

Table 5 Perspectives used by student teachers while generating questions with and without cue card, in absolute numbers and percentages

Perspective	Used perspectives without cue card		Used perspectives with cue card	
	Absolute	Percentages	Absolute	Percentages
1. Taxonomic	12	18.8	5	5.7
2. Comparison	7	8.6	19	21.8
3. Functional	3	7.2	5	5.7
4. Mechanical	29	46.4	21	24.3
5. Environmental	1	1.4	4	4.6
6. Developmental	0	0	1	1.1
7. Evolution	0	0	6	6.9
8. Medical	11	15.9	12	13.8
9. Technological	1	1.4	12	13.8
10. Ethical	0	0	1	1.1
11. Personal	0	0	1	1.1
Total	64		87	

Results Concerning the Quality of the Generated Questions

The total number of generated questions per level in absolute numbers and percentages for both conditions is displayed in Table 4. More higher order questions in levels 2, 3, and 4 were formulated while using the cue card than without using it.

Examples of questions from the different levels are the following: "What function has muscle tissue?" (level 1), "What are the differences between straight and smooth muscle tissue?" (level 2), and "What kind of muscle tissue will have arisen earlier from an evolutionary point of view (think of arguments for the different tissues)?" (level 3). The technological perspective was used frequently in level 4 questions. Examples of level 4 questions from this perspective are "How would you design a tool to make paralyzed people move?" and "Make this tube a well-functioning nerve cell, which components do you have to add and why does the nerve cell need these parts?"

Results Concerning the Perspectives Used While Generating Questions

The perspectives used while generating questions differed when the cue card was used. The questions generated without using the cue card could only be classified into seven different perspectives. The development, evolutionary, ethical, and personal perspectives were not used at all in this condition. The mechanical perspective was used most frequently, in 46% of the questions (see Table 5). However, when the cue card was used while generating questions, all perspectives were used. Use of the mechanical perspective decreased to 26%. Use of the evolutionary perspective, on the other hand, increased from 0 to 7%.

Most generated questions contained one of the keywords making them easy to categorize, or the formulated questions showed similarities with the examples of domain-specific generic questions. Examples of questions from the different perspectives generated by our student teachers with possible italic keywords according to Table 3: "*What* kind of muscles *are* present in fish?" (taxonomic), "Why are skeletal muscles *different* from muscles from the digestive tract?" (comparison), "Which *function* has muscle tissue?" (functional), "What happens when a muscle contracts?" (mechanical), "What does a muscle fiber *need* to function properly?" (environmental), "How did the different types of muscle tissue *develop* and why do these different types exist?" (developmental), "In the course of evolution, sea animals have gone up to the land to *evolve* into land animals. Which adjustments in muscle composition have been necessary for this?" (evolution), "Which muscle tissues are first affected by eating too little protein? What are the consequences?" (medical), "Can you *design* a tool for paralyzed people?" (technological), "Can you donate muscles with an organ donation? Why or why not?" (ethical), and "Would you buy or eat cultured meat?" (personal).

Results Concerning Whether the Students Found the Tool Helpful

We asked the student teachers if they thought the cue card was helpful during generating questions. Below (Table 6), we show comments, categorized into a positive ($n = 10$), neutral ($n = 4$), or negative ($n = 3$) attitude about the use of the cue card. Two student teachers responded both positively and negatively.

In summary, 17 comments were written down. Almost all student teachers formulated positive or neutral comments. Two student teachers formulated two comments, from which one comment was positive and the other more negative. One student teacher only gave a negative comment. Ten comments were positive about the use of the cue card while generating questions. Four comments were neutral; however, the student teachers felt positive about the cue card, but not that strong. Finally, three comments were negative.

Differences in Questions: Two Cases of Student Teachers

To illustrate the difference in questions generated without and with the use of the cue card, we show those of two of our student teachers (Vera and Petra, both females), plus the levels and perspectives in which these questions were categorized. Vera and Petra generated not only more questions with the cue card, but also questions from a higher quality than without the cue card. The variety in used perspectives increased for both of them.

Vera generated without the cue card four questions and with the cue card seven. The average level of the generated questions increased from 2.25 to 2.86. Without the cue card, four different perspectives were used and with the cue card five.

Table 6 Comments formulated by the student teachers about the helpfulness of the cue card during generating questions, categorized into positive, neutral, or negative

Type of comment	Comment
Positive ($n = 10$)	• *Perspectives help if I'm stuck, because it makes you think different about a topic. Sometimes the study material is to open to just design a task. The cue card then provides a way to get inspired.* (a)
	• *Yes, they form a framework.* (b)
	• *Yes, the cue card makes me think of more different topics.*
	• *Yes, they help me in designing a new assignment.*
	• *Yes, it made it easier for me to look from another angel so I can quickly generate different questions.*
	• *Yes, it gives me more direction on how I can think of questions. Even more grip to think further out.*
	• *Yes, you do get more ideas from the perspectives. Even with perspectives that you do not use often, you are thinking about it.*
	• *Yes, you are forced to think more, especially if you get stuck.*
	• *So, if you get stuck, it helps to look again from a different perspective to the matter.*
	• *Perspectives help me to think of a different angle.*
Neutral ($n = 4$)	• *A little useful, they give different angles.*
	• *Yes, a bit, lets you see the issue from the other side where you would not immediately think of.*
	• *I formulated seven questions with the cue card, but I only began to use it from question five.*
	• *Perspectives help to think creatively. However, I quickly choose the perspective that I think is most important for the exam.*
Negative ($n = 3$)	• *The cue card can force the mind in a certain direction and thereby limit creativity, so I only use the cue card if I have no inspiration.* (a)
	• *No, they steer towards shorter questions and lead me from the bigger picture.* (b)
	• *A little bit, because of this you come across different kinds of questions. Only many questions are not very useful or very involved in the subject.*

(a) and (b) mean the comments were given by the same student teachers

Questions Generated by Vera Without Cue Card

1. Explain what happens at the cellular level when you burn your finger? Use in your explanation the concepts of cell body, spurs, impulse conduction, and synapse. *(medical, level 3)*
2. Draw the path that a stimulus travels from the moment the stimulus is registered to the moment the stimulus is processed, name the parts. *(taxonomic, level 2)*
3. Why does the body sometimes respond with a reflex to a stimulus and sometimes not? *(mechanical, level 2)*
4. Figure 14 shows different types of neurons. Where are the differences and what do these differences mean for the function of this neuron? *(comparison, level 2)*

Questions Generated by Vera with Cue Card

1. What are the operational differences between the muscles of the digestive tract and the skeletal muscles? *(comparison, level 3)*
2. Why are skeletal muscles composed of other muscle tissue than muscles in the digestive tract? *(comparison, level 3)*
3. How is it possible that you can stretch and bend your arm, which muscles are involved? *(mechanical, level 2)*
4. Imagine I do a trial where I replace the striated muscle tissues with smooth muscle tissues. What happens to this person, which functions become unworkable? *(medical, level 3)*
5. What is the function of the back legs of a frog and is the construction of those muscles different than with those muscles with us, if so how? *(functional, level 3)*
6. Someone loses his calf muscle, which functions he loses in his motor skills, can this be compensated by transplanting other muscle tissue from his gut, for example? *(technological, level 4)*
7. If someone eats too little proteins, which muscle tissues are first affected by this, what is the result of this? *(medical, level 2)*

If we compare, for example, question number 2 generated without the cue card, with question number 2 generated with the cue card, we see that the first question requests a global statement about a concept as Taboada and Guthrie use in their questioning hierarchy for level 2 questions, in this case the path of a stimulus. The question asks for names of parts ("What is it?") and can therefore be assigned as taxonomic. The other question requests a more detailed explanation of a specific aspect of a concept which is contained in the question itself as is used to categorize questions into level 3 questions, which in this case is why there is a difference between skeletal muscle tissue and smooth muscle tissue, requiring prior knowledge of students about the differences in muscle tissue and places where to find them. Because the question is about the difference between two types of muscles, the question is assigned to the comparison perspective. Vera used with the cue card not only more perspectives but also other perspectives than without the cue card. She generated questions from four different perspectives without the cue card, and with the cue card she generated questions from five different perspectives. With the cue card, she used two other perspectives (functional and technological); by using the technological perspective (question number 6 with the cue card), more often higher level question are generated, which is also the case with this question. By using

different perspectives, she not only increases the quality of the generated questions, but she also broadens her question repertoire.

Petra generated without the cue card six questions and with the cue card nine. The average level of the generated questions increased from 2.00 to 2.44. Without the cue card, three different perspectives were used, and with the cue card, it was five.

Questions Generated by Petra Without Cue Card

1. Given is a drawing of a nerve cell and a nerve cell of an MS patient. Describe the differences in shape between the cells and the effect of these differences. *(comparison, level 2)*
2. You burn your finger. Describe how the signal is transmitted to the moment you withdraw your finger. Use terms from the book and draw it. *(mechanical, level 2)*
3. Valium is a soothing drug. You will find more information about this in your book. Make two drawings, one of impulse transfer without valium and one impulse transfer with valium. Specify as many parts as possible. *(mechanical, level 2)*
4. You will see three drawings of different nerve cells. In which direction does the signal go? Is it a sensory, motoric, or a switching neuron? *(taxonomic, level 2)*
5. You want to grab a book off the shelf. Describe the route traveled by the signal from the time you consider this up to the moment you move your arm. *(mechanical, level 2)*
6. The figure below shows a drawing of an action potential. In some places stand numbers. What are these stages? *(taxonomic, level 2)*

Questions Generated by Petra with Cue Card

1. Muscle balls. What is the difference between a strong muscle and a weak muscle? *(comparison, level 2)*
2. Think of an existing model/example for muscles in which you can properly express the most important functions of a muscle (contraction, relaxation, antagonist function). *(functional, level 2)*
3. Differences between smooth and striated muscle tissue. What requirements do a gull muscle and a skeletal muscle have to meet? How do you see this reflected in the construction of smooth and striated muscle tissue? *(comparison, level 3)*
4. Weight training. What do you need for better muscles? How does that work and which medicines replicate this? *(technological, level 2)*
5. You get an elastic; describe the similarities and differences between an elastic and a muscle. How can you use the elastic to make a better model of a muscle? *(comparison, level 3)*
6. Muscle disease. What is wrong? How does that work? How does it work normally? *(medical, level 2)*
7. Hamburger culture/steak culture in a laboratory. How do you grow muscle cells? What do you need? *(technological, level 3)*
8. A picture of muscles in the face. Which muscle is the antagonist? How do you know that? *(mechanical, level 2)*
9. Describe what happens to the M, Z, H, I, and A band during a full contraction, half contraction, and relaxation? *(mechanical, level 3)*

By Petra, we took as example question number 4 generated without cue card, which asks for the type of neuron which is drawn. The question requests a global statement about an aspect of the organism, making it a level 2 question from the taxonomic perspective. Whereas it can be seen that question number 9 generated with the cue card asks for the mechanism of skeletal muscle tissue, for which specific prior knowledge of the different bands is necessary to answer the question and is contained in the question itself according to questioning hierarchy level 3 from Taboada and Guthrie, making it a level 3 question belonging to the mechanical perspective. Petra also used more and different perspectives with the aid of the cue card. Without the cue card, she used three different perspectives and with the cue card five different perspectives. However, she used three other perspectives with the cue card (functional, medical, and technological), indicating that she also broadens her question repertoire.

Both Vera and Petra used more different perspectives using the cue card. They broaden their question repertoire with this, making the lessons more relevant for the students. For example, question number 7 generated by Vera with the cue card and question number 4 generated by Petra with the cue card could both appeal more to students who go to the gym, making the question more personally relevant thereby increasing student learning.

Discussion and Conclusions

It is important to ask higher order questions in class to promote the learning process among students (Chin 2007). However, the number and quality of questions asked by student teachers during practicum is low; therefore, we have developed a questioning tool which shows that when student teachers used perspective-based generic questions as a procedural prompt, not only the total number of generated questions increased, but also more higher order questions were generated. We also found that student teachers used a greater variety of perspectives when they used the cue card while generating questions, in contrast to generating questions without using the cue card. This can be seen in Table 5, which shows that the comparison, evolution, and the technological perspective are used more often. It appears that some perspectives were associated with a higher frequency of higher order questions, such as the technological perspective, which was used frequently for level 4 questions.

In addition, the student teachers gave 17 comments about the use of the perspectives. Two student teachers gave two comments, from which one comment was positive and the other more negative. Ten of the 17 comments of the student teachers were positive, and another four student teachers expressed themselves neutrally. Only one student teacher expressed himself as negative. The current findings show that with the help of perspective-based generic questions, the quality and quantity of generated questions increase.

Considering the explorative nature of the study, we chose a one group pretest-posttest design. From literature, it is known that this design can come with certain limitations. Given the short timeframe of our intervention, most of the problems which may occur while using this research design do not apply to our study, such as history effects and a maturation effect (Allen 2017). However, a priming effect may occur. Pretests can prime participants to respond in a different manner to the posttest and thus influence students' performances. To minimize the priming effect, we used another exam standard in the posttest for the student teachers to generate questions about. Now we know that the cue card does lead to more and higher quality questions; the next step would be to conduct an experimental or quasi-experimental study with

a control group and, if possible, larger numbers of student teachers to test this effect in a more rigorous way.

A second limitation of this research that requires future research refers to the phase of teaching where questioning has been elaborated. This study focused on the design phase. It shows that student teachers can formulate more questions of higher quality using perspectives, but do the student teachers pose such questions in classroom settings? Research has shown that student teachers often eliminate some of the more challenging questions (Davis, Janssen and van Driel 2016). Therefore, more research on the enactment phase is needed to investigate what kind of support effectively helps student teachers to ask higher order questions during lessons or tasks.

The results of this study show that besides that more questions were asked and that the quality of these questions increased, the cue card/tool also helps to broaden the scope of the questions. The domain-specific questioning tool stimulates to view biological topics from multiple perspectives. In general, questions and assignments generated by teachers are related to the perspective of the book used. Books often focus on the functional and mechanical perspective (Janssen and van Berkel 2015). Our questioning tool stimulates to look at a subject from different angles. As a result, students will see that biology is a broader subject than what is covered by the textbook and relationships with socially and personally relevant issues are easier established.

With research into teacher questioning, it is usual that the formulated questions are analyzed for the depth (levels) of the questions formulated and not for the width of the repertoire of the questions. We argue that it is preferable that student teachers show progression in both quality (levels) and width of the generated questions. A broad repertoire of questions is important if teachers want to make subject matter more relevant for students than only what is described in the text book, and the perspectives offer a broad repertoire of relevance. This study suggests that with research into teacher questioning, not only the level of the questions should be analyzed, but also from which perspectives these questions are derived. With the domain-specific questioning tool presented in this study, we offer a possible way to not only analyze the level of generated questions according to Taboada and Guthrie, but also a way to classify the formulated questions at the right perspective with the domain-specific generic questions (Table 3). This is an important addition to research into questioning because in the end not only the quality of the teacher questions should increase, but also the broadness of the repertoire of teachers' questions needs to be improved.

In this study, we build on previous research into questioning that have shown that domain-specific generic questions can play an important role in generating specific questions (Devolder et al. 2012). This study distinguishes itself from previous studies because we have derived directions to formulate domain-specific generic questions from research into the way in which scientists formulate questions themselves (Hintikka 2007, Rescher 2001, Thagard 2012). Perspectives appear to play a central role in generating specific questions at the start of a research line. This research shows that perspectives can also give student teachers a direction when formulating specific questions. Research on question development by scientists also shows why perspectives can help to generate specific questions. Each perspective contains an assumption about the domain that can give direction to formulate more specific questions (Hintikka 2007). The question of what is the function of a kidney will only be asked if it is assumed that the kidney has a function. The domain-specific generic questions based on the perspectives indicate which assumptions for the relevant perspective-related situations can be valid and function as a frame that can be specified specifically for each situation (Thagard 2012).

Research on question development by scientists has, as we showed earlier, provided a second mechanism for generating questions. The first mechanism is perspective-based questioning,

which we explored in this study. The second mechanism is based on the notion that new questions can also arise by answering previously formulated questions. In this study, we did not explore this second mechanism. However, it is possible that this second mechanism could supplement the first productively. In future research, it could be investigated to what extent quality and quantity of formulated questions can be increased further if student teachers are not only encouraged to formulate initial questions using perspectives but subsequently are invited to try to answer the initial questions that arise which is expected to result in more specific questions.

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