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Digital tasks with feedback as core of a mathematical learning concept for prospective teachers

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Due to the increasing importance of digitalization in our society, there are new demands on school, teaching and thus on teachers. Nowadays digital competences belong to the key competences of teachers. The acquisition of digital competences should already be developed in university education of teachers. In this regard, we refer to a university seminar aiming to support professional competences of prospective teachers in digital mathematical teaching and learning contexts. The seminar is based on learning mathematics with the digital assessment system STACK, reflecting the use of STACK, designing learning environments with STACK and, finally, reflecting school students' use of STACK. We collected data of prospective teachers' development of digital competences through interviews. First results show that prospective teachers' competences including knowledge, beliefs and motivation can be developed and differentiated.

Keywords: Electronic learning, computer uses in education, feedback, teacher education.

Introduction

“In a digital world, knowing how to use ICT and having access to such technologies are proving increasingly important for participating effectively in society” (Fraillon et al., 2020, p. 5). For this reason, gaining digital competences is a main issue for school students. However, research showed that in Germany digital competences of school students are partly poorly developed (Fraillon et al., 2020). One reason for the poor development of school student's digital competences seems to be caused by teachers (Hegedus et al., 2017; Misfeldt et al., 2016). In an international comparison, teachers in Germany use digital tools (computer, calculators, mobile devices etc.) less frequently in the classroom and also assess the potential of these less than teachers in other countries (Fraillon et al., 2020). For this reason, a main goal of university education and professional development of prospective teachers is to improve their digital competences as part of mathematics teachers' professional competences including knowledge, beliefs and motivation (Baumert & Kunter, 2013).

A contribution to this line of research will be made by this PhD-project called “Learning, Reflecting and Designing: Digital tasks with feedback as core of a mathematical learning concept”, in which we investigate in a qualitative study how prospective teachers' knowledge, beliefs and motivation could be increased in a specific seminar in the teacher education program. In this seminar, the prospective teachers experience the importance of learning mathematics with the digital assessment system STACK by learning with digital tasks themselves. Afterwards they reflect on the potential of STACK such as the opportunity of the STACK system to give individualized feedback to learners and after that, the prospective teachers design their own mathematical tasks with STACK and use them with school students. Finally, there is a renewed reflection on the STACK system, the task, the feedback and the practical application. Our main research question (RQ) is as follows:

RQ: How does learning with and designing and reflecting on one's own digital (STACK) tasks in a university mathematics education seminar affect the knowledge, beliefs and motivation of prospective teachers?

In this paper, we primarily focus on prospective teachers' beliefs referring to the potential of digital tasks with feedback including partly also aspects of knowledge and motivation.

Knowledge, beliefs and motivation

According to Baumert and Kunter (2013), professional competences comprise knowledge, beliefs and motivation. With regard to digital competences Koehler et al. (2013) provide the TPACK-model which differentiates knowledge into three main components (Figure 1): content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK).

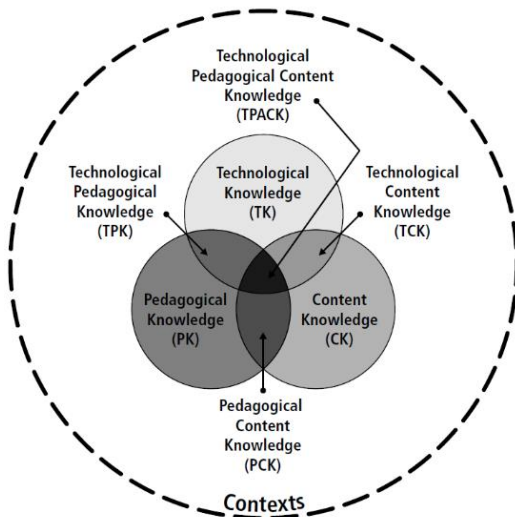


Figure 1: TPACK-model (Koehler et al., 2013)

Content knowledge comprises factual knowledge and subject-specific ways of thinking and working (Koehler et al., 2013). The pedagogical knowledge contains the knowledge about different concepts for designing learning environments, such as teaching methods, classroom management but also motivational aspects (Koehler et al., 2013). Knowledge of how to use (digital) technologies, such as hardware and software, is called technological knowledge (Koehler et al., 2013). The three main components of teachers' knowledge are set in relation to each other. Research showed that the positive influence on student performance is greater if the teacher has previously done further training on the use of digital tools and has thus acquired digital competences (Hillmayr et al., 2020). Although an

influence of the teacher on the design of lessons with digital tools has already been proven, offers for the acquisition of digital competences in university teacher education in Germany are only available to a small extent (Vogelsang et al., 2019).

Another essential competence facet of teachers are beliefs (Baumert & Kunter, 2013). We understand the term beliefs "as an individual's personal conviction concerning a specific subject, which shapes an individual's ways of both receiving information about a subject and acting in a specific situation" (Erens & Eichler, 2015, p. 136). Different dimensions of teachers' beliefs can be identified: beliefs concerning teaching, learning and a specific subject. (Fives & Buehl, 2012). Research showed that beliefs are difficult to change and that a belief change needs a substantial situational impact (Liljedahl et al., 2012). Thus, also to change prospective teachers' beliefs in a university seminar potentially needs to include a strong impact on their beliefs. Beliefs also shape the way, teachers understand teaching with digital tools (Erens & Eichler, 2015; Misfeldt et al., 2016). Specifically for the use of digital tools, Thurm et al. (2017) developed categories for teachers' beliefs about advantages, disadvantages and general issues of digital tools. In the category advantages are those teachers' beliefs that are positively disposed towards the use of digital tools in the classroom, for example, that digital tools can be used to support a change of representation (visual, symbolic). One of the

disadvantages of digital tools mentioned by Thurm et al. (2017) is the high amount of time required for the introduction of digital tools in classroom. The general category includes beliefs about the timing and thus the question at what point in the lesson a teacher should use digital tools.

Besides knowledge and beliefs, motivation is another essential competence facet of teachers (Baumert & Kunter, 2013). According to Eccles and Wigfield's (2002) expectancy-value model, motivational orientation is influenced by expectation and value variables. The expectation variable can be defined as individuals' view "about how well they will do on upcoming tasks, either in the immediate or longer-term future" (Eccles & Wigfield, 2002, p. 119). The value variable can be divided into four facets: "attainment value, intrinsic value, utility value and cost" (Eccles & Wigfield, 2002, p. 119). The value variables comprise intrinsic components (intrinsic value), rather extrinsic components (utility value) and any perceived negative aspects (costs) of an action (Eccles & Wigfield, 2002). The motivation to use digital tools in one's own lessons is positively influenced by knowledge about the use of digital tools as well as by corresponding beliefs (Ertmer & Ottenbreit-Leftwich, 2010).

Design and materials

The seminar for improving prospective teachers' digital competences

We developed a seminar concept for prospective high school and vocational school teachers focused on digital tasks with feedback within this PhD-project (Figure 2). The seminar, which is one of the elective modules in the teacher education program, is divided into four parts. In the first part, prospective teachers learn with digital tasks (STACK) themselves. For this purpose, digital tasks are provided for them to deal and to learn with. After learning with the digital tasks, the prospective teachers change their role from learner to teacher and test, evaluate and assess the given digital tasks and feedback included in the digital tasks. They also reflect the potential of the digital assessment system STACK. In the second step, the participants independently design their own digital tasks with feedback in the system STACK. In the third part, school students selected by the prospective teachers work with these tasks and comment on them, the digital format of the task and the feedback given within working on the task. In the fourth part based on students' feedback, the task, the feedback, the system STACK and the practical application are reflected by the prospective teachers. The seminar has already been conducted, evaluated and optimized in three cycles.

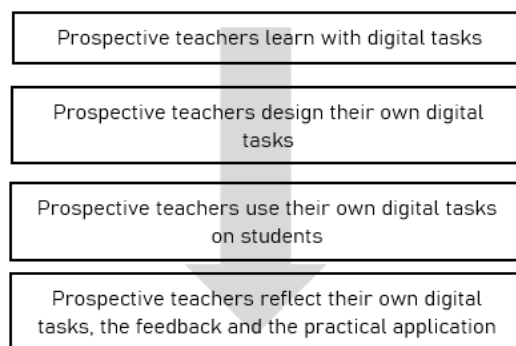


Figure 2: Seminar concept developed within this PhD-project

The digital assessment system STACK

STACK (System for Teaching and Assessment using Computer Algebra Kernel, Sangwin, 2013) is a digital assessment system in which digital mathematical tasks can be designed procedurally and conceptually (Rittle-Johnson & Schneider, 2014) and at different levels of representation (symbolic, graphic, interactive). The STACK system uses the computer algebra system Maxima (Sangwin, 2013), which makes it possible not only matching user input with stored sample solution, but also checking it for mathematical properties. Task developers are able to create a potential response tree (PRT, Sangwin, 2013) in STACK. The potential response trees, in which the input made can be examined for a specific mathematical property at each node, make individualized feedback for each user input possible (Figure 3).

The screenshot displays the STACK interface. The top section, labeled 'Task', contains the following text: 'Imagine the following situation: A student in your 11th grade class says to you: "If a function is continuous at x_0 , then it is also differentiable there." Show your student with a counterexample at $x_0 = 0$, that his statement is not correct. Your counterexample: $f(x) = |x|$ '. Below this is an 'Input Field into which $|x|$ is entered' containing the text 'f(x) = |x|'. To the right of the input field is a box labeled 'Interpretation of the computer algebra system' containing the text: 'Ihre letzte Antwort wurde folgendermaßen interpretiert: [x] In Ihrer Antwort wurden die folgenden Variablen gefunden: [x]'. Below the input field is a 'Check-Button' labeled 'Prüfen'. The bottom section, labeled 'Individualized feedback for the input made', contains the following text: 'Very good, your entered function is continuous, but not differentiable at $x_0 = 0$. You have found a counterexample for the statement of your student. To help your student understand that a function at $x_0 = 0$ can be continuous but not differentiable, it may be helpful to graph your counterexample:'. Below this text is a graph of the function $f(x) = |x|$ on the interval $[-1, 1]$. The graph shows a V-shape with a sharp corner at the origin. The x-axis ranges from -1 to 1, and the y-axis ranges from 0 to 1. Below the graph is the text: 'By graphing your counterexample, basic ideas about functions can be supported in your student, such as the object imagination. "The graph as a geometric object represents the function as a whole. Properties of the function are reflected as properties of the graph (e.g. [...] continuity, differentiability [...])." (Greefrath et al., 2016: S. 54) (Look also at: Greefrath, G., Oldenburg, R., Siller, H.-S., Ulm, V. & Weigand, H.-G. (2016): Didaktik der Analysis. Aspekte und Grundvorstellungen zentraler Begriffe. Berlin: Springer Spektrum)'. The entire interface is enclosed in a light blue border.

Figure 3: An exemplary STACK task with individualized feedback

Particularly, the possibility of STACK to provide individualized feedback is crucial since feedback is considered information that focuses on aspects of performance and understanding (Hattie & Timperley, 2007). Feedback is an effective intervention to support and optimize learning processes (Goldin et al., 2017). Feedback can increase cognitive performance, motivation and the feedback-recipients' willingness to make an effort. Furthermore, feedback can support learner individually and according to their potential. Within digital learning environments there are numerous possibilities to give feedback on learning processes (Goldin et al., 2017). The individualized, differentiated feedback for each user input seems to be crucial but often there is given rather simple and evaluative feedback (categorization into right or wrong) (Fraillon et al., 2020).

Design of the study

The sample for the data collection consists of three prospective teachers from each of the three seminar cycles. A main method for collecting data of the prospective teachers were semi-structured interviews which took place two times in each seminar. The semi-structured interview guide contains three domains (Figure 4). The first domain refers to beliefs and motivation from the learner's perspective. Therefore, this domain is about the prospective teachers' university education. This contains the use of digital tools in university studies and the attitude towards digital tools. The second

and the third domain ask for beliefs and motivation from the teachers' perspective. In the second domain, we ask for the motivation to use digital tools and digital tasks in the classroom in the four facets that Eccles and Wigfield (2002) describe (attainment, intrinsic and utility value as well as cost). The third domain concerns school and teaching in particular. There we ask for beliefs towards digital tools and digital tasks with feedback while teaching and self-efficacy to design lessons with digital tasks. In this context we also collect beliefs about feedback in school context.

Furthermore, we work with written comments from the prospective teachers on different digital tasks. Within the written comments, the prospective teachers should vary the given tasks, design new

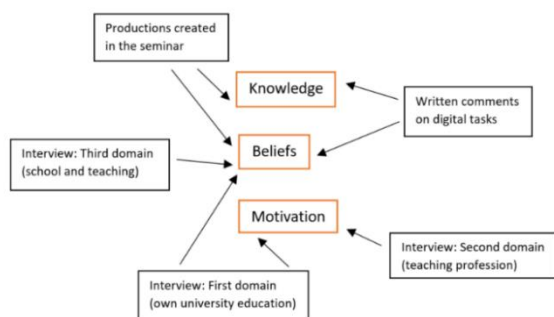


Figure 4: Methods and which competence facets we ask for within these methods

feedback to different inputs and name advantages and disadvantages of the digital format and the digital feedback. With this method, we want to collect professional knowledge which contains variation of tasks and designing feedback, but also beliefs towards digital tasks and digital feedback.

Moreover, we analyze productions from the prospective teachers, which are created in the seminar. This includes their own digital tasks, the written reflection on their own digital task, the

designed feedback and their final term paper. With this, we want to survey the professional knowledge as well as the beliefs about the use of digital tasks in lessons (Figure 4).

We analyzed the data using content analysis. For this purpose, the competence facets knowledge, beliefs and motivation are subdivided into different categories, such as learning with digital feedback, advantages of the digital format for teachers and negative aspects concerning the STACK system.

Findings

In this paper we exemplarily show interview excerpts. In the first example, Adrian names the possibility to get feedback directly while working on digital tasks:

Adrian: [The system gives] feedback directly. This means that the student works on a task and during the work he already gets feedback on what is correct, what is wrong and why he does something wrong. This gives a great potential to directly address and counteract the problems a student has while working on the mathematical task.

The expressed belief relates to learning with digital tasks with feedback and applies more to an advantage of feedback than of the digital task itself. Adrian only mentions superficially the structure of feedback and the containing components. He rather focuses on one function of direct feedback which is the early prevention of misconceptions. This is not only a belief, but also concerns the knowledge facet TPACK (technological pedagogical and content knowledge, Koehler et al., 2013). TPACK describes the knowledge about mathematical digital learning environments. In this context, it is necessary for a teacher to know about the functions of the STACK system as well as to recognize misconceptions and problems of students while working on a task and to be able to design individualized feedback.

In the next example, Jacob's statement relates to teaching with digital tasks with feedback from the teacher's perspective and applies to an advantage of the digital format of the task:

Jacob: For me as a teacher it is important that I can see what the students' learning level is. The students' inputs are listed in a table. There I can also see how many attempts [to solve the task] were needed, what misconceptions existed among the students and what feedback the students received.

He explains that the digital format gives the teacher an accurate overview of students' missed attempts and misconceptions. This can form the basis for a better assessment of the students' performance on the one hand and for planning the following lessons on the other hand. This statement also refers to the utility value of motivation (Eccles & Wigfield, 2002). Digital tasks and the associated better overview on the students' learning level are useful for a teacher to plan further lessons. This is a rather extrinsic reason for using digital tasks in one's own lesson. The facet of knowledge addressed here is technological knowledge (TK, Koehler et al., 2013). The teacher needs to know about the function associated with digital tasks and how to handle the STACK system.

Patrick's statement concerns teaching and learning with digital tasks and applies to an advantage of the digital format and the digital task:

Patrick: The digital format of the task gets students motivated to start working. I believe that the students have more fun working digitally than calculating a task from the textbook. Especially students who are not mathematically inclined are more likely to want to work on digital tasks and try them out.

The first part of Patrick's statement is about teaching with digital tasks. He mentions the positive attitude of the students towards digital tools. Therefore, it will be possible to get students into action. The second part of the statement concerns learning with digital tasks. It explicitly refers to students who are not mathematically inclined. The inhibition to deal with mathematical content and to do something wrong can decrease through the digital format of the task. This also concerns the utility value of motivation (Eccles & Wigfield, 2002). The digital format of the tasks is useful to get students motivated to work and therefore the use of digital tasks in one's own lessons is influenced rather extrinsically. This statement also concerns TPACK (Koehler et al., 2013). Patrick focuses on cognitive activation within mathematics teaching which can be supported by digital tasks.

Not all beliefs towards digital tasks with feedback are positive. In addition to the advantage explained above, Jacob also mentions a critical point towards working on digital tasks. He discusses whether the process of working on the task is really digital:

Jacob: In case of a complex digital task that cannot be solved in head but, for example, requires five to ten intermediate steps before solution can be found, these steps must be written on a sheet of paper in analogue form. This means that the process finding a solution is partly not digital, but only the input and evaluation of the solution are digital.

Jacob explains that students need an analogue medium like a sheet of paper to solve a complex digital task. Therefore, the task as well as the evaluation of the input can be described as digital but not the process of solving. This belief concerns learning with digital tasks with feedback and the process of working on a digital task respectively and applies to a disadvantage of digital tasks because not the entire process of working can be considered digital. Jacobs' statement also relates to the facet cost of

motivation (Eccles & Wigfield, 2002). Within this facet, all negative aspects of the use of digital tasks with feedback in the classroom are summarized.

Discussion and conclusion

The presented study investigates how prospective teachers' knowledge, beliefs and motivation towards digital tasks with feedback can be changed through a specific seminar in the teacher education program. First results show that prospective teachers' beliefs are varied. Some of the beliefs relate to feedback as a part of a digital task. Other beliefs concern teaching with digital tasks and associated with a better overview of student performance. Beliefs about learning with digital tasks were also expressed such as that students are more motivated to engage with a mathematical topic because of the digital task format. We can thus see that the prospective teachers' beliefs relate either to teaching and learning with digital tasks as well as to the specific subject of feedback, what has already been described by Fives and Buehl (2012). The fact that the prospective teachers adopt multiple perspectives could be due to the seminar concept presented. The prospective teachers first learn with digital tasks themselves, taking the learner's perspective. In the seminar, they then change to the designer's perspective when designing their own digital tasks and finally to the teacher's perspective when using them with school students. Furthermore, the beliefs can be classified into the categories advantages, disadvantages and general issues found by Thurm et al. (2017). It also becomes visible that the competence facets knowledge, beliefs and motivation are not disjoint. Many of the prospective teachers' statements can be assigned to categories of beliefs as well as categories of knowledge and/or motivation.

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