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Digital competencies of pre-/in-service teachers—an interview study

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Since the role and the availability of digital technology in society is growing, educators need to increasingly more often decide when and what digital technology to integrate into their teaching. Thus, those decision-making competencies need to be developed and measured especially for pre-service mathematics teachers. Therefore, we conducted an explorative interview study to understand the variety of argumentation and justification of pre- and in-service mathematics teachers on whether to use or not use digital technology in the teaching phases of Prediger et al. (2013), and what criteria they use in making those decisions. The analysis shows that (1) based on the arguments and justifications different level of decision-making competencies can be distinguished and (2) the recorded criteria on whether to use or not use digital technology are suitable for reflective practicing of such decisions.

Keywords: Digital competencies, Pre-service teachers, Student teacher evaluation, Technological advancement, Decision making skills.

Introduction

Given the growing role of technology in society and education, as well as the growing number of digital technologies available to teachers (Ally, 2019; Clark-Wilson et al., 2020), it is important that the technology-related competencies of educators constantly evolve and valid instruments to evaluate such competencies are necessary. Educators have to decide increasingly more often when and what technology to integrate into their teaching practice to be effective and meet the demands of society and their learners — not only because of curricular guidelines/standards — but also because the aim to prepare their students for a work environment in the future which will be even more digitalized and driven by technology. In summary, the skill and the knowledge of educators to make appropriate decisions on when and what digital technology to use in teaching is driven by the increased digitalization of society and an increasing number of digital technology available and thus of high importance to educators. Not surprisingly the skill and the knowledge of selecting suitable digital resources have been added to educator competency frameworks like ISTE Standards for Educators (International Society for Technology in Education, 2000) or the DigCompEdu (Redecker, 2017). Even though the DigCompEdu framework lacks references to the educator’s orientation towards implementing technology in classrooms, it has been cited as one of the most compressive frameworks in its suitability of educators’ need to integrate digital technology (Tabach & Trgalová, 2020) and therefore is used as a basis for our research. DigCompEdu entails twenty-two competencies and one of them is “Selecting digital resources,” which is defined as “To identify, assess and select digital resources for teaching and learning. To consider the specific learning objective, context, pedagogical approach, and learner group, when selecting digital resources and planning their use.” (Redecker, 2017, p. 20). It should be noted that although increasing the efficiency of an educator because of the use of digital

technology is not included in the DigCompEdu definition, it has been cited as a significant factor in the selection process of educators (McCulloch et al. 2018). Given the importance of the competence “Selecting digital resources,” it needs to be fostered as part of the educational program of pre-service teachers; to evaluate such processes, the competency needs measure instruments and items which reflect that importance. With that in mind, we aim to develop open-end items for an external assessment and conducted this interview study to better understand the decision processes of pre- and in-service teachers on the use or not use of digital technology in teaching. In the following sections, we first describe the theoretical models, we used in preparation for this interview study. Subsequently, we present the results of the study with pre-/in-service mathematics teachers in Germany.

Theory

In the planning of the interview study, it became apparent that (1) a clear definition of digital technology within education and (2) a model to describe the situational context of teaching settings is required. Thus, we briefly introduce the digital technology definitions given by Clark-Wilson et al. (2020) and the model of teaching phases of Prediger et al. (2013).

Definition of digital technology in education

Clark-Wilson et al. (2020, pp. 1225–1226) group digital technologies by function. The function of the technology inherently determines its use within a teaching situation and are termed as follows.

- a) Organizing: “As a support for the organization of the teacher’s work (producing worksheets, keeping grades)”
- b) Representation: “As support for new ways of doing and representing mathematics”
- c) Collaboration: “As a support for connecting, organizing in communities, communicating and sharing materials”
- d) Independent: “...a commercial and industry driven function, which supports students’ more independent work and focuses on practicing and assessing previously taught mathematical knowledge and skills in a range of online formats.”

We use these technology categories since they align with the definition of the competency “Selecting digital resources” and with aspects of the competencies in the area of “Teaching and Learning” of the DigCompEdu framework.

Core teaching phases by Prediger et al. (2013)

Prediger et al. (2013) describe a model of teaching that can be used to design teaching arrangements and to make situational teaching decisions. In the model, four core phases are differentiated: *Connecting (C)*, *Exploring (E)*, *Systemizing (S)*, and *Practicing (P)*. These core phases are defined by their didactic function, cognitive activity, and epistemological quality. Whereby the didactic function designates the perspective of the educator and the cognitive activity encompasses the perspective of the learner. The authors state, that other aspects of teaching e.g., creativity and collaborative exchange can be developed within each phase by providing those stimulations. This aligns with the digital technology categories of *Collaboration* and *Independent* as outlined in the previous section. In the context of this paper, we use the model of Prediger et al. (2013) to evaluate the decision-making

processes regarding whether to use or not to use digital technology within each phase. Digital technology can be used in all four teaching phases to either support a didactic function, the cognitive activity or both. (Büchter et al., 2019; Hillmayr et al., 2020; Peschek & Schneider, 2002; Reinhold et al., 2020; Swanson, 2020). While some of the studies are directly attributed to a particular phase, others are applicable to all or multiple phases.

Research questions/evaluating educators' competency of "Selecting digital resources"

To understand the selection and decision process on whether to use or not to use digital technology in teaching lessons of (prospective) teachers, we conducted exploratory interviews with in-service and pre-service teachers to answer two research questions (RQ).

RQ1: How do pre-service and in-service teacher reason for or against the use of digital technology in the context of a specific learning subject, learner age group, and teaching phase?

Regarding this question, we let the interviewees choose their preferred content and learning group to reason on familiar grounds. All four phases of the model of Prediger et al. (2013) are addressed by the respondents.

RQ2: What criteria do pre- and in-service teachers use when deciding on the use of digital technology in teaching?

With this question, we specifically inquired what role the age group of the learner and the learning content have in the decision process and on the learner/educator perspective.

Methodology

We have used semi-structured interviews in the explorative study. Next to some demographic questions, the respondents were first asked to explain along with the four phases of teaching on a specific mathematics subject and student group whether to use or not use digital technology. In the second part of the interview, we enquired about the use of digital technology in teaching—not restricted to a particular subject and student group. This two-prong approach was taken to gain an understanding of how participants would reason within a specific setting as well as in more general terms of teaching with digital technology. We interviewed five pre- and five in-service mathematics teachers in Germany. Regarding the former, two interviewees were at the beginning (1st and 2nd semester) and three at the end of their studies (6th, 8th, and 10th semester); they studied with an emphasis on special or on lower secondary education. Regarding the latter, teaching experiences varied between four and thirty years in lower and upper secondary education. The broad diversity of participants was chosen to get insight into the maximum variability of answers and reasoning. All interviews were conducted in German and transcripts were coded using qualitative content analysis (Mayring, 2000).

Qualitative analysis of the interview study

In the following, the results of the coding are presented. Citations are abbreviated and designated as either pre-/in-service teacher indicated by the prefix "Pre-T-"/ "In-T-" followed by a number indicating the semesters of study or the years of teaching as well as the point in time in the interview. Only the English translations of the interview coding by the authors are presented to save space.

Results regarding research question 1

Two different approaches within the first section of the interview were taken by the participants. One participant, a pre-service teacher in the sixth semester, stated that the selection of digital technology cannot be made by the teaching phases and that the decision is rather based on the type of technology. For the analysis, this interview was excluded as although the approach is valid it does not answer the research question at hand. The responses of the remaining participants were used as the basis for answering the imminent research question using a two-layered approach. In the first layer, we differentiated the type of arguments and justifications and in the second layer, we reviewed the types of digital technology groups used within each phase.

For the first layer of analysis, we differentiated argumentations with (i) no argument, (ii) arguments(s) which were not substantiated or overly generalized, and (iii) argument(s) substantiated by either a didactic function, cognitive activity, or own application. First, we provide some examples of the applied coding system and later a summary of the types of argumentations clustered by participant groups. The following response is an example of “no argument,” indicating to not use digital technology in the *Connecting* phase because of no knowledge of technology to be useful in this phase.

[06:17] – Pre-T-2: *Connecting. Well. I would say no...At the moment I cannot think of a use for software to capture one's previous experience. I would do that I think rather in a conversation ...*

An instance of a response with an overly generalized argument and justification reads like this.

[09:38] – Pre-T-2: *So first of all, I think in general it makes sense to use it [digital technology], because I just think that it totally focuses the attention of students.*

In addition of being an overly generalizing argument, it could be debated if this line of argumentation is correct, as studies suggest that prolong use of digital technology or media can have adverse effects on learners' cognitive ability and attention span (Lodge & Harrison, 2019). A response with an argument substantiated by a didactic and cognitive function is the following explaining the use of a quiz app [Biparcours] versus paper & pen worksheets in the *Connecting* and *Exploring* phase.

[11:16] – In-T-10: *So now I use a digital tool [Biparcours], which is not explicitly mentioned in the curriculum... I found this methodologically useful here for motivation and to promote self-directed learning. The [students] can work through the questions in the [Bipar] course at their own pace and receive automated feedback and continue...*

The app is used to reactivate the learner's prior knowledge of a related subject and letting them explore the new content. The decision is explicitly supported by the didactic goal in those phases and fostering self-learning. Also the motivational aspect of technology on the cognitive activities of the learners has been mentioned in the reasoning. The response also implies the aspect of automated feedback and leveraging aggregate instead of individual results to assess the outcomes of the phases. This speaks for the aspect of educators' efficiency because of technology. A response using in the argumentation a cognitive perspective is given next.

[07:45] – In-T-4: *I think that when you're exploring and discovering new mathematical facts, the effort is very high... and if you can relieve this high cognitive hurdle that's involved in the discovery, in some form by having the technology take away certain repetitive sequences of actions, like the construction, which is done identically over and over again, we can outsource that...*

Following the outlined coding the responses of the participants were categorized by (1) the four teaching phases, (2) the type of argumentation and substantiation of the arguments and (3) the types of participants. We differentiated three groups, Pre-T-2, Pre-T-8/10, and In-T-x.

The analysis yielded the following results: First, the arguments and the level of justification progresses from “Pre-T-2” who provide only arguments in the *Exploring* phase which were substantiated by either their own experience in using digital technology or by providing examples of the use of digital technology, to Pre-T-8/10 who provided arguments supported by cognitive perspective for the *Connecting* phase and arguments supported by cognitive as well as didactic perspective for the *Exploring* phase. And then to the in-service teachers who provided arguments for all four phases supported by didactic, cognitive aspects or own application of technology and are most comprehensive. Second, regardless of the participant group a justification is given by the respondents for the *Exploring* phase. Thirdly, only the in-service teachers provided substantiated arguments for the *Practice* phase. In summary, based on the coded argumentation and justification pre- and in-service teachers can clearly be distinguished.

The second layer of the coding reviews the technology groups *Organizing*, *Representing*, *Collaboration*, and *Independent* in the context of the teaching phases. The results by the three participants groups Pre-T-2, Pre-T-8/10, and In-T-x are shown in Table 1. Pre-T-2 named only technologies in the *Representation* group (and here also only GeoGebra) but were able to argue for their use in the *Exploring* phase like Pre-T-8/10 and In-T-x. The latter however did not only provide a more comprehensive list of technologies in the group (e.g., GeoGebra, Excel, CAS) they also were able to identify and argue for the use of digital technologies regarding the *Independent* and *Organizing* group in this phase. The * in the table denotes phases in which participants argued not to use digital technology or did not see the value of it. Their level of argumentation was assessed in the first layer of the coding.

Table 1: Digital technology groups by phase and participants group

	Pre-T-2	Pre-T-8/10	In-T-x
Connecting	None*	None*	Independent, Organizing
Exploring	Representation	Representation	Representation, Independent, Organizing
Systemizing	None	Collaboration	Collaboration
Practice	None	None	None*

Peculiar is that the In-T-x see the value of the technology grouping *Independent* in the *Connecting* phase, but do not see the same benefit in the *Practice* phase, in particular they do not see the aspect of using digital technology for assessments. A possible explanation is that the use of digital technology for assessments is not widespread and not necessarily the main didactic objective of the phase. It also becomes apparent in this layer of coding, that the decision of using digital technology in a particular teaching phase is a decision on how a digital technology supports the didactic function and a cognitive activity. Since the didactic function and the cognitive activity in the four phases are discriminative, different technology groups are highlighted for a phase. The aspect of “independent

working” supported by the technologies in that grouping, although potentially applicable to all four phases, is more relevant in the *Connecting*, *Exploring* and *Practice* and to a lesser extent relevant in the *Systemizing* phase. The same applies to technology in the *Representation* grouping, which enables to present content in multiple and new forms and thus is more relevant in the *Exploring* phase and not or to a lesser extent relevant in the other phases. *Collaboration* technology, which enables the sharing of information -- educator to learner and learner to learner – was assessed to be more relevant in the *Systemizing* phase, where the didactic goal is to link the learning of the individual to the group. Inductive the hypotheses can be made that the *Representation* technology used in the *Exploring* phase is more dependent on the teaching domain and that the technology in the grouping *Independent*, *Organizing* and *Collaboration* are neutral to the teaching domain. Based on the two layers of analysis we can summarize (1) the competency, meaning the argumentation and reasoning skills as well as the knowledge about digital technology in education distinctly differs and progresses from Pre-T-2 to In-T-x. (2) The technology groups differ regarding the teaching phase and distinct technology groups can be assigned to a single phase respectively.

Results regarding research question 2

In second part of the interviews, we investigated the selection criteria the participants use in their decision processes. The cumulative view of the results is organized by (i) learner age and abilities, (ii) learning content, and (iii) educator perspective. The criteria are formulated either as continuum statements (younger to older learners, less to more) or dichotomous yes/no statements. Criteria which are limited in their scope because of the context they were provided in or the participating teaching group being either special-, lower- or higher education are marked accordingly.

Learner age and abilities (In-T-x)

- The younger the learners, the lower the cognitive demand of the technology can be and the lesser own personal devices are available. Also the younger the learners, the more oversight is required to ensure the digital technology is used responsibly and in the intended didactic manner.
- Motoric abilities (Pre-T-2, Pre-T-8/10)
 - o No: Do not use technology, if it is likely that it gets damaged.
 - o Yes: If it enables the inclusion of learners [overcomes impairments of learners].

Learning Content (In-T-x)

- Yes: If the curriculum demands the use of a particular technology.
- Yes: If the content can only be taught using a particular technology.
- Digital technology should enable or support dynamic and different forms of representations and the ability to outsource repetitive activities which are not the focus of the didactic goal.

Educator perspective (In-T-x)

- Technology by commercial providers generally puts a higher burden on the user either because of financial costs, login and registration requirements or the data collection by the provider.

From the list it becomes apparent that the participants use no hard rules at what learner age to start with using digital technology. It should also be noted that some of the participants stated that they weigh in their decision and selection of technology different criteria and are making tradeoffs when deciding. Otherwise the list of criteria has been deduced from the participants responses and should

be seen as an accumulation of the teaching practice of the in-service teacher in combination with the arguments and reasoning given in the previous section.

Discussion and outlook

In the interview study, we were first able to show that by the argumentation and justification of whether to use or not use digital technology that we can differentiate between three groups (pre-service teachers at the beginning and pre-service teachers at the end of their studies as well as in-service teachers) within all four phases of the model by Prediger et al. (2013). In the *Exploring* phase, the differences are seen regarding the justification, whereas in the other phases, the differences are seen regarding argument and justification. Additionally, whereas the in-service teachers provided multiple digital technologies for each technology group by Clark-Wilson et al. (2020), the pre-service teachers especially at the beginning of their studies were only able to provide a few examples in the *Representation* group. Either because they are not aware of digital technologies and/or they did not bring them in context with the teaching phases, which needs to be considered in the development and measurement of the digital competency “Selecting digital resources.” To verify the reliability of the findings a quantitative study should be conducted.

Secondly, there are indications that the role of the technology groups, as described by Clark-Wilson et al. (2020), differs regarding the teaching phase and that the technology groups can be assigned to a teaching phase in the model by Prediger et al. (2013) respectively. As such, the decision process on the use of digital technology in a teaching phase can be seen as a decision regarding digital technology and not necessarily regarding a specific teaching phase.

Thirdly, although the technology grouping of Clark-Wilson et al. (2020) and the model of the core phases of teaching of Prediger et al. (2013) were created within the context of mathematics education, the findings of the interview study suggest that they are transferable to other teaching subjects/domains. Digital-technology grouped as *Independent, Collaboration and Organizing* potentially is common across teaching subjects and the technology in the group *Representation* is teaching-subject specific. In order to validate these findings, we are planning a quantitative pre/post survey with participants outside of mathematical contexts using the offered approach in this interview study.

The study is limited to pre-service teachers at one university and in-service teachers of one region in Germany, all in context of teaching mathematics. Nevertheless, we were able to provide insights into the decision-making process on the use of digital technology. The accumulated list of technology decision criteria will require further review with regard to its application in the development process of pre-service teachers. Especially the scope of the decisions they will have to make in their future teaching practice needs to be considered versus the decisions they are subjected to by others namely the school leadership or curricular guidelines.

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