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# Key aspects of using personas in mathematics teacher education

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*Pre-service teachers should be trained and prepared to develop digital learning resources. Therefore, they need insight into the characteristics and demands of mathematics students, which personas, prototypical representatives of homogeneous student groups, can provide. The study aims to discover aspects of personas relevant to basic teacher training. We accompanied four pre-service mathematics teachers and interviewed them during one term while they were developing digital learning materials using personas. We analysed the data using grounded theory and qualitative content analysis approaches. The results indicate that the following aspects of using personas are vital for teacher education: Personas as an information tool, personas as a planning and feedback tool, triggering reflection processes through working with personas and continuity in working with personas.*

*Keywords: Personas, digital learning resources, basic mathematics teacher training.*

## Introduction

For integrating new technologies into mathematics classrooms, the training of pre-service mathematics teachers is essential (Lavicza et al., 2022; Weinhandl et al., 2021). Developing digital learning resources for teaching and learning mathematics is vital for this. If pre-service mathematics teachers are to create high-quality digital learning resources during their training, they should be able to address students' characteristics. One way to make it easier for pre-service mathematics teachers to consider these is to use personas. Personas are simplified representations of a homogeneous group (Minichiello et al., 2018; Sundt & Davis, 2017) and originally come from user experience research (UXR). For our study, personas from a previous study (Weinhandl et al., 2022) representing homogeneous groups of mathematics students were used by pre-service teachers for developing digital learning resources. In this context, the research question of our study is:

What aspects of personas and using personas when developing digital mathematics learning resources by pre-service teachers are relevant to basic teacher education?

To address and answer the research question, we combined approaches of qualitative interview studies, think-aloud techniques, and grounded theory.

## Theoretical background

To connect the current body of knowledge to our research aim, the following section links personas research, TPACK (technological, pedagogical, and content knowledge) and mathematics teacher education for using technologies to the context of our study.

### Mathematics student personas

Personas, a tool of UXR, are simplified representations of a homogeneous user group (Minichiello et al., 2018; Sundt & Davis, 2017). Since personas enable putting oneself in the shoes of potential system users, personas can facilitate the development of digital systems (Antle, 2008). In particular, the needs, desires, fears and technical experiences or access requirements of user groups should be considered in personas development (Lilley et al., 2012; van Rooij, 2012). Personas have been used

in STEM education at the tertiary level (Guy, 2017; Vorvoreanu et al., 2016), but personas of secondary mathematics students have been little researched. In an earlier phase of our study, personas of secondary mathematics students were developed (Weinhandl et al., 2022). Now, personas' practical use by pre-service teachers in developing digital learning resources is scientifically accompanied. Using personas should make it easier for pre-service mathematics teachers to take students' characteristics and demands into account when developing digital resources.

### **Mathematics teachers' technological, pedagogical, and content knowledge (TPACK)**

For successful integration of technologies in teaching mathematics, teachers need technological, pedagogical, and content knowledge (TPACK: Mishra & Koehler, 2006) and appropriate contextual knowledge (Mishra, 2019). For the present study, pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPCK) are of particular importance: PCK is the knowledge of which teaching approaches are suitable for the content. TPK includes knowledge about the possible digital tools for a task, knowledge about pedagogical strategies and the ability to use them. TPCK represents the synthesis of these areas of knowledge and is the basis for sound teaching with technologies. TPCK requires an understanding of how to represent concepts, including using technologies; pedagogical techniques for constructive use of technologies to teach content; knowledge of concept learning and problem solving using technologies; knowledge of students' prior knowledge and epistemologies; and knowledge of how to build on existing knowledge and develop new or strengthen old epistemologies (Mishra & Koehler, 2006). In addition, contextual knowledge, i.e., knowledge about available technologies or what policies one operates in, is also essential for good teaching (Mishra, 2019). According to Açıkgül (2020), to develop TPACK, pre-service mathematics teachers should be given the opportunity to plan, implement and evaluate technology-enhanced lessons in their education. Cooperative work and discussions about using technologies with others should be facilitative to developing TPACK. According to Jang & Tsai (2012), classroom experiences can contribute to the enhancement of TPACK. Furthermore, Patahuddin et al. (2016) emphasise that authentic classroom experience, including considering students' demands and characteristics, contributes to improving mathematics teachers' TPACK. Personas can be a tool to facilitate the integration of mathematics student needs and characteristics into the training of pre-service teachers. In our study, the TPACK concept is not used to analyse the data, but as a design element of the project. As TPACK is incorporated in the design of digital learning materials, it serves as a linking theory for the discussion of the results. TPACK is thus part of the context of the study, along with the personas.

### **Mathematics teacher training for using technologies**

Pre-service mathematics teachers' basic education is essential in acquiring TPACK in whether, how and how well they use technologies in their teaching. Doğan (2012) emphasised more than a decade ago that pre-service mathematics teachers should be prepared to use different computer-based activities. Therefore, according to Clark-Wilson and Hoyles (2019) and Doğan (2012), mathematics teacher training should provide experiences with specific digital tools and software. These experiences should make it easier for pre-service teachers to see technology's benefits (Gurevich et al., 2017; Weinhandl & Lavicza, 2019). However, according to Odell et al. (2020), using technologies

can also lead to a decline in mathematics students' performance, making it more vital to support pre-service mathematics teachers in using technologies. In our study, pre-service mathematics teachers are supported in developing digital competencies and learning resources by experienced teachers and university staff. Furthermore, the pre-service mathematics teachers in our study do not work individually but in groups, which facilitates the formation of a kind of community of practice (CoP), which could contribute to the professionalisation of pre-service mathematics teachers. According to Voskoglou (2019) and Wenger et al. (2002), a CoP is characterised by a shared concern/passion among individuals and interactions about it that lead to the deepening of knowledge.

## **Methods and methodological background**

In this study, mathematics students' personas developed in a previous study (Weinhandl et al., 2022) were used to identify aspects of personas that might be significant in teacher education. Our research is constructive grounded theory in line with Charmaz (2006) because our study explores something entirely new, the results of our study are grounded in the data, and other researchers in a different context could probably obtain different results.

### **Participants and context of our study as well as data collection and time frame of our study**

For this study, mathematics students' personas were used in a project at the University of Linz (FLINK: <https://www.jku.at/flink-in-mathe/>), in which pre-service teachers and experienced teachers (with school and university background) are engaged in creating digital mathematics learning resources using the software GeoGebra. Four of these pre-service teachers, who are at the end of their bachelor's or the beginning of their master's degree, were included in our study.

For our study, pre-service mathematics teachers were given work assignments for which they had to use mathematics students' personas. One such assignment was to create or select learning resources for a specific persona. One of these learning resources, which according to the pre-service teachers is especially suitable for a persona who has motivational problems and needs step-by-step guidance, has been translated into English and is available at: <https://www.geogebra.org/m/dqcdrcmx>. After completing these assignments, qualitative interviews were conducted with the pre-service mathematics teachers using think-aloud techniques. Our study's time frame consists of three task phases, thus three points in time of data collection. Altogether, our study lasted a little longer than one term. The interviews were conducted both face-to-face and online, whereby in the online data collection the pre-service mathematics teachers could show their materials using screen sharing.

### **Data analysis and development of results as well as validation processes in our study**

First, the transcribed interview recordings were skimmed, facilitating the coders to identify the initial themes of the newly collected data. Then, the data were analysed in line with grounded theory approaches (Charmaz, 2006; Strauss & Corbin, 1997) and qualitative content analysis approaches (Kuckartz, 2019; Mayring, 2015). In the first step, open coding was carried out in line with the corresponding techniques (Charmaz, 2006; Strauss & Corbin, 1997), facilitating the coders to open the data and develop initial units of meaning. The codes of the three interview rounds consist of a keyword, a definition, and a prototypical example. The entire codebook can be found at the following link: [https://www.jku.at/fileadmin/gruppen/87/Sonstiges/Codebook\\_Englisch.pdf](https://www.jku.at/fileadmin/gruppen/87/Sonstiges/Codebook_Englisch.pdf). After each

interview round, the individually developed open codes were compared at a face-to-face meeting of the four coders, and similar codes were merged. This approach enabled us to develop new codes of a higher abstraction level, representing the code set at the beginning of the coding in subsequent rounds of interviews. After the second coding round, the resulting codes were used to provisionally form categories that were further developed after the third coding round. In our study, according to Kuckartz (2019) and Mayring (2015), qualitative content analysis techniques, in particular summarization techniques, were used for the further development of provisionally formed categories.

To ensure the quality of our results, we considered the recommendations of Jonsen & Jehn (2009), according to which mixed methods, different sources and different coders should be used in qualitative and explorative studies. In our study, we combined qualitative content analysis and grounded theory approaches, used four coders, conducted interviews, and used think-aloud techniques. After each coding cycle, we determined intercoder reliability ratios and average intercoder reliability according to Cohen's Kappa (Cohen, 1960) and Miles & Huberman's (1994) formula. Cohen's Kappa and the intercoder reliability in line with Miles and Huberman's formula were always  $>.9$ , which indicates a high intercoder reliability.

## **Results**

Personas enable pre-service teachers to gain insight into the characteristics of mathematics students to create digital learning resources. In the following, the study results show which aspects of personas are relevant for teacher education. The quotations in the following section have been translated by us from German into English and pseudonyms were used.

### **Personas as an information tool (regarding characteristics of mathematics students)**

For creating digital mathematics learning resources, it is necessary to have an information tool that gives an overview of the characteristics of different mathematics students. The data show that personas can be such an information tool containing information about goals, needs, challenges & problems and the enjoyment of mathematics students. The data of our study show that such information is used to successfully create differentiated teaching materials by pre-service teachers. For pre-service mathematics teachers, a compact presentation of the information is essential.

Nora, round 1: For most of the personas, it says how much they like mathematics or also how much effort they want to put into the mathematics work. This was important or good because we then simply developed some materials for interested students.

### **Personas as a planning & feedback tool (for differentiated learning materials)**

Personas are used explicitly as a planning and feedback tool in developing differentiated teaching and learning materials in our study. Personas as a planning tool significantly support pre-service mathematics teachers in conceptualising new learning resources. Personas as a feedback tool allow feedback on the fit of a created material for different students.

Olivia, round 1: [...] by always thinking, is the material only for the one average student, or am I perhaps addressing several people from the personas [...]. Yes, but in retrospect, or even in advance when creating the material, you think about who the material is actually for.

Personas can be particularly important for differentiation in creating materials; the data show that for pre-service mathematics teachers, it is crucial to consider the student body's heterogeneity.

Differentiation occurs in line with interests, gender, performance, and willingness to perform, difficulty and the structure of the tasks. The pre-service mathematics teachers state that it is essential to promote the students' enjoyment and that there should be no reduction in fears and problems.

Flora, round 2: What I have noticed recently is that I have noticed that I have to cater a bit more to different interests, also in terms of design and so on. So, not all students have my interests.

### **Triggering reflection processes through work with personas (related to the user)**

As the data show, working with personas stimulates an intrapersonal reflection process among the pre-service mathematics teachers regarding questions about their student self. However, it is also evident in the data that the view can be directed away from the "I" to the fact that there are other types of students. Therefore, working with personas can stimulate an interpersonal reflection process in addition to a reflection on one's person. According to the data, the pre-service mathematics teachers recognise that students are different and what their differences and similarities can be based on.

Antonia, round 1: [...] I think it's good to be reminded that maybe some people aren't that into it or that maths just isn't that important to them. Well, I quite like maths and I think it's quite good to be reminded that there are also some who don't see maths as so important.

The pre-service mathematics students also reflect the relevance of differentiation. However, in addition to recognising the existing heterogeneity in the student body, limits to differentiation are also highlighted according to the data. The data show that working with personas leads to a broader perception of the facets of individual students and that they can thus be perceived within the framework of a more comprehensive picture. A reflection takes place in this regard on the part of the pre-service mathematics teachers in our study, especially concerning the students' environment, and there is a more active perception of the topics, interests and problems outside of mathematics lessons.

Antonia, round 1: What might also be interesting [...] is how they are in the other subjects. I think that is often really interesting because there are so many other subjects and maybe if someone is interested in drawing or somehow artistic, then you can also get them on board in such a way that you give such examples.

### **Continuity**

According to the data of our study, long-term engagement is central to working with personas. In order to be able to explicitly or implicitly incorporate knowledge gained from the personas into the development of differentiated learning materials, the personas must be recalled repeatedly. The data show that a continuous engagement with the personas can take place in the form of repeated observation, or it needs an impulse in the form of a concrete work assignment.

Olivia, round 3: [...] especially this incentive, that the interview then comes, was good for us to deal with it again and again. Because otherwise, you get so lost in what you're doing. [...] I don't know if we would have repeatedly dealt with it otherwise. So, I think that was important.

Using grounded theory and qualitative content analysis approaches in our study shows that for the basic education of mathematics teachers, personas as an information tool, personas as a planning & feedback tool, triggering reflection processes through work with personas and continuity in using personas are important.

## Discussion and conclusions

Our study aimed to shed light on which aspects of personas and using personas are important for mathematics teachers' basic education. Personas can be used, on the one hand, as an information tool for characteristics of mathematics students and, on the other hand, as a planning and feedback tool for differentiated learning materials and thus serve as a helpful tool in the creation of learning resources during teacher education. Furthermore, working with personas can trigger reflection processes related to the user, especially on heterogeneity. To maximise the influence of personas on material development and reflection processes, continuous engagement with them is essential. In the study, personas proved to be a helpful tool for creating digital learning resources that consider the characteristics and demands of mathematics students. Among other things, the pre-service mathematics teachers paid particular attention to needs, which is also an essential aspect to consider in development, according to Lilley et al. (2012) and van Rooij (2012). The pre-service mathematics teachers in our study created technology-enhanced learning materials, which according to Açıkgül (2020), should have contributed to the development of their TPACK and was further enhanced by the cooperative collaboration in groups. According to Patahuddin et al. (2016), authentic classroom experiences that consider students' needs and characteristics also improve TPACK. However, due to lack of contact of pre-service teachers with students, it is difficult to provide such authentic experiences. Since, according to our results, personas can serve as an information tool for the characteristics of mathematics students, they enable the realisation of authentic classroom experiences. Thus, they can also contribute to the development of TPACK in pre-service mathematics teachers. Furthermore, we found out that working with personas can lead to intra- and interpersonal reflection processes. Reflecting on how content and teaching approaches should be combined to meet students' needs could contribute to the development of pedagogical content knowledge (PCK) and thus, according to Mishra & Koehler (2006), to the development of TPACK. Our findings show that continuity is an important aspect of engaging with personas. Since TPACK, according to Jang and Tsai (2012), is also continuously built, a longer-term engagement with personas in the creation of digital learning resources can go hand in hand with the continuous development of TPACK.

Thus, for mathematics teachers' basic education, personas enable pre-service teachers to get in touch with students' demands and characteristics and to use them as an information tool or planning and feedback tool for material development and as a trigger for reflection processes. Furthermore, the use of personas in the development of digital learning resources can contribute to the development of TPACK. The study's results contribute to research on personas and using personas in mathematics education, which until now has been very little explored.

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