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Personas Characterising Secondary School Mathematics Students: Development and Applications to Educational Technology

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Abstract: Information technology plays an increasingly prominent role in our personal and professional lives. It also plays an important role in schools, and especially in mathematics education. To realise their full potential in education, technologies should be designed in a way that addresses the characteristics of the target students. In the context of learning mathematics, students often experience anxiety with regard to the content that needs to be learnt; therefore, this work considers mathematics anxiety as a characteristic that should be particularly relevant when designing technologies that assist with teaching and learning mathematics. The development of personas, i.e., prototypical and simplified user descriptions, is a widely used tool in user experience (UX) research that supports design processes. In this methodological paper, we combine this UX methodology with a grounded theory approach. This combination of methodologies could facilitate the establishment of guidelines for developing personas representing secondary school mathematics students, which constitutes the goal of this paper. We review existing persona development techniques in other fields and adapt them to the context of secondary mathematics education using qualitative secondary data. Our aim is to provide a research approach that produces a better understanding of students' characteristics, needs, and fears. Despite limitations in terms of the amount of data included in developing and piloting this methodology, this work forms the basis for increasing the usability of educational technologies and for adapting them to individual learning styles to reduce mathematics anxiety.

Keywords: educational technologies; mathematics anxiety; mathematics education; student characteristics; personas; UX research

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1. Introduction

The development and use of personas is well established in user experience research (UX research) [1,2]. Personas are short and simplified descriptions of the potential users of a technology. They provide technology developers with authentic and lively representations of target user groups so they can focus design processes on the characteristics of the users [2]. Moreover, in the context of education, personas could be a valuable tool for communicating student characteristics to developers of technologies and technology-enhanced learning environments. One of the biggest issues in teaching and learning mathematics is students' fear of mathematics [3]. Personas can help create designs that take the students' fear into account, thus helping to tackle students' mathematics anxiety.

We follow Ashcraft's [4] definition that describes mathematics anxiety as "a feeling of tension, apprehension, or fear that interferes with math performance". Mathematics anxiety differs from general anxiety in that it is situation-specific, and it manifests itself in mathematics-related environments [3]. There are a multitude of possible origins of mathematics anxiety. These origins could be, for example, (a) teachers' high standards for students' schoolwork while providing little cognitive or motivational support during lessons; (b) students' negative experiences in mathematics lessons; (c) traditional mathematics teaching with strict rules; (d) teaching methods that do not fit the students' preferred learning styles; (e) students' lack of confidence in their own mathematical skills; and (f) lack of belief that mathematics is meaningful [4–6].

There are a variety of approaches to reduce students' mathematics anxiety [7]. These include concentrated efforts to improve student performance, heuristic instead of algorithmic teaching, special classwork on microcomputers, provision of special equipment (e.g., calculators), and special techniques for presenting the material (e.g., tutorials, small groups, and self-study). When designed appropriately, technology-enhanced learning environments can help implement these approaches into teaching and learning mathematics; therefore, developers of such environments need to be aware of potential student anxieties and means of reducing these anxieties. Personas in the form of short and simplified descriptions of the potential users of a technology, and authentic and vivid representations of target user groups, could enable technology-enhanced learning environments to take students' anxieties about mathematics into account to a greater extent, thereby contributing to improving the quality of teaching and learning mathematics.

Personas have already been applied in general education research for various reasons; for example, to outline the attitudes of university teachers in STEM fields towards active learning [8]; to capture and present perceptions that university teachers have of students in their undergraduate distance learning courses, and to adjust the design of distance learning environments to fit student needs [9]; to redesign an online data visualisation platform for university teachers in STEM fields [10]; and to design a user-focused online search engine for peer-reviewed papers based on the needs of researchers [11]. These applications of personas in education all focus on teaching and learning in tertiary education. There has not yet been systematic research on the development and use of personas in the context of teaching and learning mathematics at the secondary school level.

In our educational research, we apply the persona methodology to the characteristics, needs, and fears of secondary school mathematics students. To transfer this methodology to the educational context, we define users primarily as students who use technologies, especially in mathematics, as a resource to support their learning. In line with the typification of qualitative studies according to [12], our research can be classified as a grounded theory research approach. Based on this approach, we develop persona prototypes that support a user-centred approach to designing digital tools for mathematics education. More specifically, in this paper we pursue the following research question: How can persona development techniques be used to identify upper secondary school mathematics students' needs, characteristics, and fears which are related to technologies in Austria?

We expect that the use of personas based on these techniques will contribute to a better understanding and a more transparent presentation of the common needs, characteristics, and fears of secondary school students, which are related to technologies in mathematics education.

To reflect the conceptual and productive aspects of our study, we have divided the literature review and our paper's theoretical background into two parts. The first part is a literature review of the technologies used in teaching and learning mathematics, and of the characteristics, needs, and fears of mathematics students. In the second part, we focus on the goals and techniques of persona development.

2. Materials and Methods

2.1. Literature Review and Theoretical Background

The technologies for teaching and learning mathematics on the one hand, and the characteristics, needs, and fears of mathematics students on the other hand, form the two pillars of the literature review. These two pillars are the foundation of teaching and learning mathematics in many countries and they establish the starting point of our research. We aim to highlight the methodological progression of technology development strategies; therefore, the literature review emphasises the use of technologies.

2.1.1. Technologies in Mathematics Education

The development of digital technologies has caused a transformation in education, and has benefited mathematics education in particular [13]. Not only have the advantages of the uses of technologies in teaching and learning mathematics been recorded, but the potential pitfalls have also been studied extensively [14]. Over the past 20 years, technologies that are designed to support human–computer interactions have been newly incorporated into the technological toolkit of teaching and learning mathematics (e.g., [15]). A more recent development is the out-of-school diffusion of new technologies into students' lives and an increased pressure for schools to integrate these novelties into classrooms [14]. In our work, the term technology refers to all electronic tools, such as hand-held calculators, tablets, or notebooks that enable, but are not limited to, mathematical calculations or visualisations, as well as the use of suitable software or digital environments (e.g., Computer Algebra Systems, dynamic geometry software); however, few of these new technologies were originally developed for teaching and learning purposes in a school context, which is now causing challenges for teachers and students.

Technologies in Mathematics Curricula and Policy Documents. Technologies have been included in key positions of curricula and other education policy documents in many countries. For example, in the United States of America, the intention of using educational technologies in the National Education Technology Plan is to "transform learning experiences with the goal of providing greater equity and accessibility" [16]. In Austria, the use of modern technologies when learning mathematics has become an essential pillar of the curriculum; thus, the curriculum also requires teachers to integrate modern technologies into their teaching [17]. The mandatory use of technologies when teaching mathematics has made it necessary to adapt technologies to the demands of teachers and learners. Recommendations by transnational organisations, such as the EU or the OECD, to use technologies in education, have excited the development of, and research on, technology-enhanced environments for teaching and learning mathematics. The assumption underlying these recommendations, and subsequent developments, is that the use of technologies promotes competency-based teaching which, in turn, nurtures problem-solving skills [18]. Furthermore, technologies could facilitate reducing the mathematics anxiety of students [7,19]. According to Blazer [19], students' mathematics anxiety could be reduced, especially if students learn mathematics cooperatively with the help of computers, various software, and websites with mathematical content. In our research, we use personas to explore new ways of guiding the development of technologies for use in teaching, learning, and skill development, with the intention of reducing students' anxiety with regard to mathematics.

Using Technologies to Improve Teaching and Learning Mathematics. To improve teaching and learning in schools, technologies should not be considered by themselves, but rather as part of an interplay between teachers and learners, as "it is the process of appropriation led by the teacher and the students that eventually transforms the digital artefact into a mathematical instrument" [20]. Introducing technologies to the classroom creates, together with the students, their personal backgrounds, and the school environment, a "socio-technological assemblage" that teachers may utilise to enhance the learning of mathematics [21]. Technologies can be used in the classroom to stir interest in both tackling mathematical problems and acquiring conceptual knowledge [22]. Moreover, technologies can also help promote collaboration between teachers and between students, as well as between teachers and students in order to facilitate the learning process [20], or to reduce mathematics anxiety [7,19]. Technologies affect how students think about and understand mathematics; for example, by including haptic, visual, or collaborative features [23]. Furthermore, for more than 30 years, using technologies for the teaching and learning of mathematics has been considered to have the potential to reduce students' mathematics anxiety [7]. The requirements for technologies in the teaching and learning of mathematics are subject-specific. Digital technologies are "protean (usable in many different ways)", "unstable (rapidly changing)", and "opaque (the inner workings are hidden from users)" [24]; therefore, teachers require technological pedagogical content knowledge (TPACK) to integrate technologies into their teaching so that it can yield benefits [24]. Furthermore, teachers need, among other things, computer literacy in order to reduce mathematics anxiety among teachers [25]. For students to minimise their anxieties concerning mathematics, it might also be important for their teachers to have no anxiety surrounding the teaching of mathematics.

2.1.2. Characteristics of Mathematics Students

To effectively design technologies that assist with teaching and learning mathematics, as well as technologies that support teachers and learners, it is necessary to have a clear understanding of the characteristics, needs, and fears of mathematics students.

As early as the late 1970s, mathematics teachers were recommended to adapt their teaching to the individual characteristics and expectations of students, as well as to their future career prospects, and to the newly emerging applications of mathematics in different areas [26]. In this regard, it should be considered that mathematics students differ in terms of whether they prefer to receive new information verbally—either spoken or in writing—or visually, using, for example, diagrams or demonstrations [27].

Technologies have the potential to facilitate individualised learning, as teachers can provide personalised settings and support for learning based on students' current needs, and they can allow for autonomy during the learning process [28]. Advantages of individualised learning in technology-enhanced learning environments may include increased student motivation, active participation in the construction of knowledge, and more flexible mathematical thinking; this could foster the development of problem-solving skills [13,22,28]. The provision of technology-enhanced learning environments that enable and promote individualised learning requires a sound knowledge of the goals, needs, and anxieties of school students, on the part of both educators and developers alike. In particular, knowledge concerning mathematics anxiety, and consideration of mathematics anxiety, is of great relevance, as mathematics anxiety is related to poor performance in mathematics [7] and avoidance behavior [4]. Especially in these areas, personas could provide insight that may facilitate supporting students in learning mathematics.

Personas could be well-suited to describe different types of students with—at times—very different needs, preferences, and fears when learning, and thus, they could help developers of educational technologies, as well as developers of technology-enhanced learning environments, to consider all the students in a classroom.

2.2. Personas in UX Research

Personas are concise descriptions of potential users that support system developers in addressing the characteristics, needs, and fears of potential users. Personas were originally developed in UX research; however, the use of personas could also be beneficial in the context of teaching and learning [29,30].

2.2.1. Characteristics and Definitions of Personas

User needs have often been described based on impressions and anecdotal narratives [2]. To achieve high usability and a high-quality user experience, it is crucial to include knowledge of user needs and emotions that is already in the design of a system [31]. Especially if children or young people are the users of the systems in question, it can be challenging for software developers to interpret user needs and behaviours correctly due to lack of time, expertise, or resources [32]. Personas offer a way to address these needs within these constraints. In our study, personas were created with limited financial resources and without third-party funding, which is why our approach could serve as a template for other organisations or institutions that have limited resources.

Personas are archetypes of system users that are developed in a design context [29,30,32]. Special attention should be paid to the needs, desires, fears, technical experience, or access requirements of these fictional users during development [9,30]. Each persona encapsulates the characteristic incentives and behaviours of a typical subgroup of potential users [10,33,34]. Personas provide a useful view of users and their needs [2]. Although the various descriptions and definitions of personas often differ, the majority of experts agree on the basic components of personas (see Figure 1). It is essential for persona development that the characteristics of a homogeneous group of potential users are focused upon the description of a single person. This avatar is presented by a name, a picture, their wishes and fears, as well as their background and hobbies [9,29,30,33,35].

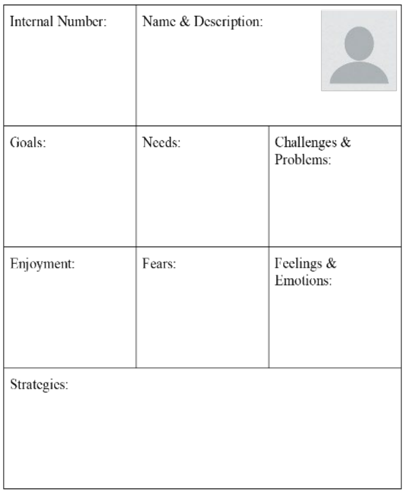

Figure 1. Persona template created in this project for educational contexts.

2.2.2. Uses of Personas

Personas are used to render the target user groups of a technology relatable, thus promoting empathy among potential users [2,10,30,31]. This guides developers to systematically consider user needs in the design and development process of technologies [10,29,35]. Personas should only ever be used in the specific context for which they were designed [36]. The use of personas in the educational context should improve the understanding of the pedagogical and technical needs of students, provide insights into the student population, and make the teachers' implicit knowledge about students explicit.

Personas were initially developed for application in user interface design and based on this, they were subsequently developed for application in user experience research [37]. Over time, however, personas have been increasingly used in other areas as well. A well-known example of such an application that is related to teaching and learning is used in librarianship [2,35,36]. Personas have also been used when creating learning environments that focus on student experience in education [9], and specifically, in mathematics education [8,10,29]; however, personas have not been explored to a great extent in the context of teaching and learning mathematics in secondary schools. In this study, we apply UX methodologies in educational research by using personas to identify student needs. We expect that these personas will be used to support the development of technologies that advance the teaching and learning of mathematics in secondary schools.

2.2.3. Methodology of Developing Personas

The first step in the development of personas is to define the target group and the purpose of using personas in the given context [10,32,36]. Experts differ in their recommendations of best practice in the development of personas; however, what many expert recommendations have in common, is the idea that persona development is an iterative process based on extensive and continuous data collection [2,32]. The first step when developing personas is to collect qualitative data from and about the target user group, and then to combine these data into the first draft of personas [10,30]. These drafts are referred to as "ad-hoc personas". Ad-hoc personas are, for the most part, based on data collected from single individuals about subjective experiences, which include assumptions about the user group [9,29]. The goals of ad-hoc personas are to enable developers to relate to the potential user groups and to provide researchers with guidelines for planning further data collection [29]. With the data obtained from a more targeted data collection, "data-based personas" are then developed, and the data from potential user groups are evaluated with the intention of reducing the number of components that researchers may interpret subjectively [29]. Developers should then use the data-based personas to understand the goals, needs, wishes, and fears of potential user groups, and they should apply these insights in order to guide the system development process. The quality and usefulness of personas can be increased and maintained at a high level by validating the developed personas [2,29,32].

The depth and quality of personas can vary depending on the nature, extent, and quality of available data. Moreover, when resources are scarce, as is often the case in education, rudimentary personas can be developed and used. Different options for collecting data related to persona development will be discussed in the following section.

2.2.4. Collecting Data for Persona Development

To develop a persona, several different kinds of data sources should be used (see Figure 2). Persona development should be based on both qualitative and quantitative data [38], as well as on primary and secondary data [2]. Primary data are collected directly from members of potential user groups; secondary data are gathered from other sources, and they concern members of potential user groups. Context should be added to make the personas more lively and relatable [32–34].

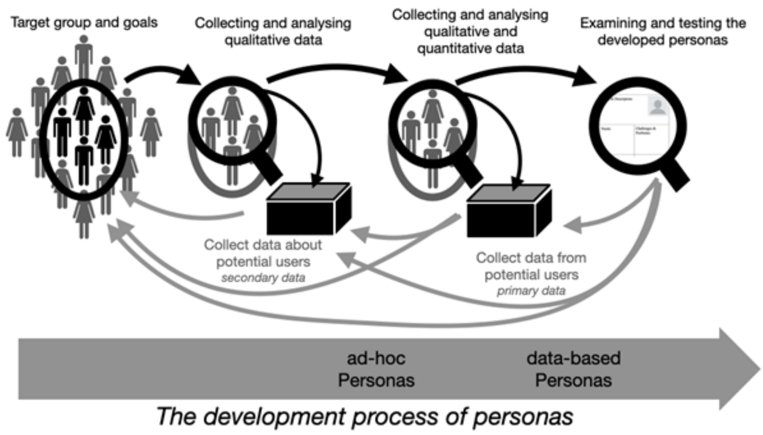

Figure 2. Data collection and persona development process.

Even though all sorts of data can be used in persona development, most often, qualitative data are used [35]. A classic tool for collecting data is to conduct interviews [30,34,35]. Interviews may be conducted directly with potential users of a system [36] to obtain primary data, or with experts regarding potential users [32] to collect secondary data. Another data collection method is observation, either via participant or non-participant observations. [32,34,35]. Job shadowing is a purpose-built observation method, where researchers accompany a user of a system over a long period of time to study their uses of, and interactions with, a system [11]. Compared with these methods, web surveys facilitate creating a large amount of data that cover a wide geographical range [30]. In addition to qualitative data, quantitative or background data should also be used in the development of personas when possible. Typical data of this kind include age, gender, field of study, or school type of potential users [11,38]. These data can be collected directly from a potential user of a system, or they can be taken from previously collected data available in databases.

2.2.5. Analysing Data

Grounded theory is a systematic way of collecting and processing qualitative data to initialise, and by using appropriately adapted iterations, to inductively develop a new theory [39,40]. In this paper, we pursue a grounded theory approach to create personas that represent different types of users of technologies or systems from raw qualitative data.

2.2.6. Criticism of Developing and Using Personas

A major criticism of persona development is that the process is rather subjective, informal, and unscientific [30,31,34]. Another point of contention is that, frequently, secondary rather than primary data are often included in the persona development process, and the samples are often quite small [10,38]. The use of insufficient data in the design process can lead to ambiguous and superficial personas that do not realise the potential of the method; in addition, persona development often requires substantial resources that are not always readily available [34].

To reduce the degree of subjectivity, multiple means of quality improvement and quality assurance are recommended for use in persona development [34]. To proceed systematically, a public system with predefined guiding questions for collecting data should be developed [31]. People from multiple areas in persona development should be involved [29]. Participants in the persona development process should involve stakeholders, to contribute knowledge of potential users; actual product users, to substantiate previously developed personas; and system developers, to assess usability [29]. Personas should be refined iteratively using continuously collected data to maintain validity and quality [2,35,36].

3. Using Persona Techniques to Characterise Secondary School Mathematics Students

As this paper's primary goal is to present methodological advances rather than empirical research findings, the resulting methodology for developing personas in the context of teaching and learning mathematics is presented in this section. Additionally, the resultant personas from the application of this methodology are presented.

To create an initial version of mathematics student personas based on secondary data, we proceeded in four steps. First, we (a) defined a target group of mathematics student personas, then we (b) collected statistical and administrative data on mathematics students in the target group. Next, we (c) collected and analysed secondary data, and finally, we (d) validated the results of the data collection and analyses. In the following, we explain our approach, the purpose of which is to present the creative methodological work of using persona development techniques in the field of secondary mathematics education.

3.1. Target Group of the Mathematics Student Personas

To develop mathematics student personas, it is necessary to define the population that should be represented by the personas. This is quite straightforward in a school context, due to the organisational and institutional framework conditions, such as age-homogeneous classes or different school types, as prescribed by legal structures.

According to the official authority [41], there were more than 6000 primary and secondary schools in Austria in the school year 2018/2019. They were attended by more than 1.1 million students. There are 26 school types in Austria, each with its own focus and objectives, from which finer subdivisions can be made, especially at the upper secondary level.

In our research, we focused on students at the upper secondary level of general secondary schools. Mathematics is a compulsory subject that will be tested in their final examinations. The use of higher-order technologies is permitted and necessary at this level. The minimum requirements for higher-order technologies include displaying graphs of basic functions; numerically solving equations and systems of equations; determining derivative and integral functions; ensuring that numerical integration is possible; and supporting methods and procedures of statistics and probability calculation [42]. In Austria, most classes use mathematical software packages that can be used on a notebook computer (e.g., GeoGebra) or high-end handheld devices (e.g., Casio products, TI-Nspire). This choice of technologies is also reflected in textbooks (e.g., [43]) and during professional teacher development opportunities (e.g., [44]).

Secondary school students work towards this school leaving examination [45] in which innovative technologies and digital competencies play an important role [17]. Consequently, modern technologies are of great significance for students in the upper levels of general secondary schools, rendering this group of students particularly important for our research.

3.2. Statistical and Administrative Data

The starting point for the development of personas was data on students and schools from Statistics Austria, as well as the National Education Reports from 2015 [46] and 2018 [47]. The task and goal of statistical and administrative data in persona development are, on the one hand, to provide an initial overview of the basic population of the target group, and on the other hand, to ensure that the data collection can be carried out in a representative manner. These statistical data [48], as well as general and administrative data on the Austrian school system and on teaching and learning in Austrian schools [46,47], were taken into account when developing our questionnaire for collecting secondary data.

3.3. Collection of Secondary Data

3.3.1. Participants

To develop personas that reflect the goals, needs, challenges, enjoyment, fears, and feelings of upper secondary school mathematics students in general education schools, secondary data were collected. In our study, secondary data refers to data that were not collected directly from the students themselves, but from other people related to the students. These people were upper secondary school mathematics teachers and student teachers of mathematics. To collect data on students' characteristics from an expert perspective, rather than a perspective that draws upon personal biases, we chose to base this work on secondary or complementary data drawn from the pedagogical expertise of participating teachers. The in-service and pre-service teachers contributing to our study were chosen from urban and rural areas. We devised this spread so that it took into account both place of work and students' learning, because the general and administrative data on the Austrian school system [38] show that there is a significant difference in student success depending on whether one attends a school in an urban and densely populated area, or in a rural and sparsely populated area. There were slightly more women than men in this group.

We included students with diverse socio-economic backgrounds. In densely populated areas, we selected schools from both affluent and less prosperous neighbourhoods to recruit participants from. In our sample, the ratio of approximately 5:1, which represents the number of students that came from public and private general secondary schools, respectively, corresponds to that of the overall student population in the school year 2019/2020 [49].

With regard to teachers, we included more teachers in the middle and at the end of their respective careers, rather than early-career teachers. This selection was made in line with the statistical data on teachers and schools in Austria, and was thus intended to represent the student population as well as possible.

3.3.2. Research Tools to Collect Secondary Data

The secondary data were collected with the help of anonymous online questionnaires over a period of 10 weeks. The online questionnaires were sent to 56 in-service and 139 pre-service teachers of mathematics. Of these, 10 in-service and 51 pre-service teachers completed the questionnaire. In order to guarantee full anonymity, and thus increase the willingness of teachers and students to participate in our data collection, we did not ask for any personal data. Waiving the collection of personal data ensures that we cannot make any statement about whether the submitted questionnaires correspond with the population of invited persons, and thus to the Austrian population.

When collecting data, teachers were asked to describe one student from their upper secondary school mathematics classes that they considered typical, addressing the goals, needs, challenges, joys, fears, and feelings of that student. A specific notion of what might render a student typical was deliberately not suggested to the teachers, since they would likely consider different types of students to be typical. The multitude of teachers that contributed a description of a student that they considered to be typical resulted in a pool of various types of students. This formed the basis for developing the personas (see Section 3.4). Teachers also provided general information such as gender, or whether they considered the student to be good at mathematics. In our study, pre-service teachers were asked to describe themselves during their time as an upper secondary school student, and they were also asked to describe a former classmate of theirs who was either not good at mathematics in upper secondary school or did not enjoy learning mathematics. This approach to collect data from pre-service teachers was intended to ensure a sufficient supply of data on keen and successful students, as well as less keen or less successful students, for the development of our personas.

3.4. Analysis of Secondary Sata

To develop mathematics student personas for upper secondary school from the collected data, and to present these data, we established a methodology that consists of a three-step analysis (see Figure 3) based on the methodology of grounded theory (see Section 2.2.5).

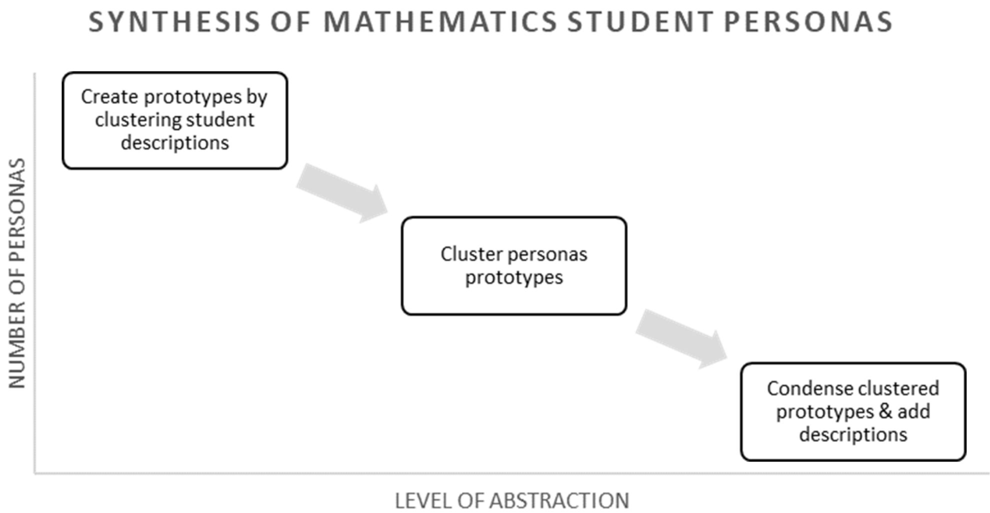

Figure 3. Process of synthesising mathematics student personas from student descriptions.

In the first step of this analysis, two authors proceeded independently. Each coded the collected questionnaires and created initial clusters of comparable mathematics student descriptions. For each initial cluster, a prototypical mathematics student description and a label were created and added. In this first step of generalising, which therefore increased the level of abstraction, the researchers formed nine and twelve initial clusters of mathematics student descriptions, respectively.

In the second step, we increased the level of abstraction of these persona prototypes. To this end, each researcher formed categories for the 21 prototypes obtained in the first step. Next, each researcher distilled characteristic features from each of the formed categories into a short description, and they added a keyword, thus creating new, more abstract personas.

In the final step, the researchers joined the six respectively five new personas from the second step, clustered them and created descriptions and labels for each of the five resulting clusters jointly. In this final step, the original data were condensed further and the level of abstraction of the personas increased (see Figure 3).

Token statistical and administrative data were added to the mathematics student personas that had been obtained in this three-step analysis, using the secondary data, to make the personas more relatable.

To improve the quality and increase the validity of the mathematics student personas, we also worked with secondary school mathematics teachers who were not involved in the first stage of our research. When selecting teachers, the emphasis was again placed on gender balance and choosing a balanced representation of teachers who teach in urban and rural schools. The personas that emerged from our three-step analysis were presented to 16 teachers. As part of the validation process, teachers were asked to comment upon whether they thought there was a substantial likeness between each of the mathematics student personas and actual students that they had taught or were teaching.

Some peripheral details were deleted from the persona descriptions in cases where the teachers agreed that these details were not typical of the real-life students that they would otherwise associate with the respective persona.

This methodological paper focuses on the process of persona development. The mathematics student personas resulting from our particular study will be described and analysed in future research.

3.5. Improving the Quality of Personas

Recalling Section 2.2.6, we implemented the recommendations of Ferreira et al. [31] and Miaskiewicz et al. [34]. The data on the characteristics of upper secondary school mathematics students were collected from in-service and pre-service teachers with diverse backgrounds, levels of experience, and gender. The data were first processed independently by two different researchers. These steps were taken to reduce the degree of subjectivity in our research. To reduce subjectivity and improve authenticity further, the developed personas were validated by school practitioners. Both face-to-face approaches and digital media were used to increase the sample size when collecting data and when validating the resulting personas.

3.6. Final Product of Methodology Application: Personas

To sum up our results, our approach was to develop personas that revealed five different prevailing combinations of characteristics of Austrian upper secondary school mathematics students (see Table 1). One notable outcome is that some students can be categorised as having a clear mastery-oriented attitude towards their mathematics learning, and they choose proactive strategies. Their anxieties, if they have any, relate to the failure to fulfil external expectations and to not living up to their potential. In contrast, others prioritise avoiding failure, and they adopt rather defensive strategies. They are frequently confronted with test anxiety, and they have doubt if their mathematical knowledge is sufficient to complete mathematical tasks and pass exams.

The resulting personas are included in this paper as Supplementary Materials. Further details on the nature of common combinations of specific characteristics and their realisations as concrete mathematics student personas will be presented and discussed in a subsequent paper.

Table 1. Summary of the personas identified in the project.

Persona 1	10th grade 16 years old Male	High sense of responsibility; high interest in mathematics; misses advanced content in lessons; enjoys discussing mathematics; uses external resources; afraid of losing status.
Persona 2	11th grade 17 years old Female	Academic household; eager to achieve good grades; considers mathematics important for her university education; enjoys solving problems and receiving good feedback; demands access to many additional exercises; afraid of not excelling in exams.
Persona 3	10th grade 16 years old Male	Non-academic household; wants to know exactly what the passing requirements are; attempts to pass with the least amount of effort; willing to cheat; afraid of having to put significant effort into learning; indifferent towards mathematics.
Persona 4	9th grade 15 years old Female	Migrated to Austria with her family when 7 years old; wants to impress teachers; has high regard for mathematics and people who are good at it; test anxiety; tries to identify and follow fixed patterns in problem solving.
Persona 5	9th grade 15 years old Male	Supported by family; average goals, in that he tries to complete tasks *satisfactorily*; requires guidance; afraid of failing in exams; ready to use any means necessary to complete exams and tasks.

4. Discussion

Integrating technologies into schools has prompted the development of new approaches to teaching and learning, as well as to teaching and learning new content, and new competencies in mathematics classrooms. The use of personas is a way to better understand the needs and fears of potential users of teaching and learning technologies. This improved understanding can help ensure that actual user needs and fears are considered in the development of educational technologies from the beginning. Our study aims to synthesise a methodology for describing the needs and fears of secondary mathematics students using persona development techniques in educational research to support the development of user-centred educational technologies.

4.1. Technologies in Teaching and Learning Mathematics

The use of technologies has a long tradition in teaching and learning mathematics, with applications becoming more diverse [13,14]. Technologies such as augmented reality now have the potential to assist learning by blending the real world and the digital world in school [15]. The diversity of programmes and technical systems, the range of possible applications, and the increasing spread of technologies in school-based learning have led to a increasing number of people that use technologies for school-based learning purposes; consequently, this has also led to a greater variety of needs, fears, and requirements. In our study, we developed a means to identify, and present in the form of personas, typical needs, fears, and demands of students. These personas can support developers of technological systems in terms of targeted and optimised system development.

The constant presence, and the multiple uses of technologies in the lives of children and young people, have also led to the development of new knowledge and to new ways of developing, exploring, and practising mathematical concepts in the classroom [20]. Our research provides methodological guidelines for how to distil information concerning the needs and anxieties that students experience when learning new mathematical concepts. These results could be useful for developers or other stakeholders in the field of educational technologies.

Ease of use is the most important factor determining the extent to which many use technologies, and especially mobile technologies, in their personal, professional, and school lives [21,22,28,50,51]. Moreover, the ease with which a tool can be used depends on the users' prior knowledge and skills, and on their demands of the system. The creation of personas when applying the methodology developed in our research has the potential to facilitate the consideration of prior knowledge, skills, fears and demands of users in the design of technological systems, and thus, it can increase the usability of the systems.

Technologies, or various representations of the content that needs to be learnt, could contribute to reducing mathematics anxiety [7]. Using personas could make students' mathematics anxiety visible and contagious. Knowing about students' potential mathematics anxiety could support developers of educational technologies and learning environments to take mathematics anxiety into account during the design process. Supposing that mathematics anxiety has already been considered in the design process of learning tools, students might be better motivated, or the learning process might be more easily adapted to the learning styles of students. This could contribute to reducing students' mathematics anxiety, thereby improving students' mathematics performances [4–6].

4.2. Personas

The results of our study show that, by using personas, UX methodologies can be used to present the characteristics, goals, and fears of potential users of a technological system.

Using various methods to increase the quality and validation of personas are recommended to reduce elements of subjectivity in the personas [34]. In this context, it is also recommended that as many people as possible, from as many areas as possible, are consulted during the data collection to reduce the subjectivity of the personas [29]. These recommendations proved very useful over the course of our study. By involving practitioners from the technical (GeoGebra) and pedagogical (upper secondary school mathematics teachers) fields, our study's personas could be further developed and specified. Through this further development and specification of the personas by working with practitioners, it should also be possible to increase the personas' quality.

From the resulting personas, it can be observed that anxiety appears in different forms. On the one hand, personas representing students who aim for high grades and for a good mastery of the subject are hardly concerned with anxieties related to mathematics. Their anxieties are instead related to living up to the expectations of others or failing to demonstrate their skills (Personas Johannes Friedrich and Aurelia Höfinger). On the other hand, personas representing students who were not concerned about their grades indicated anxieties related to a lack of mathematical knowledge (Personas Dominik Ghali and Manuel Winkler). We expect this to be of great importance for developers of educational technologies with regard to their responses to the different situations students face in terms of their anxieties.

In our future papers, we will introduce uses for personas in developing educational technology tools for Austrian students, as well as pedagogical approaches that successfully utilise these applications in classrooms.

4.3. Limitations

Our guidelines for developing personas based on mathematics students were based on an analysis of a limited amount of secondary data. To increase the quality, validity, and generalisability of the resulting mathematics student personas, it will be essential to use other methods such as observation, quantitative research approaches, or job shadowing in further research. Moreover, there should be a vertical and horizontal expansion and a condensation of the mathematics student personas in future research. A vertical extension of the mathematics student personas means that the characteristics, fears and needs of primary school students, lower secondary mathematics students, or college level students are also taken into account. Horizontal extension and condensation imply that more data on upper secondary school mathematics students are collected, analysed, and then included in the current personas. A significant and crucial vertical compression of the mathematics student personas can also be achieved by including primary data.

Supplementary Materials: The personas resulting from the application of the methodology presented in this paper can be downloaded at: https://www.mdpi.com/article/10.3390/educsci12070447/s1.

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References

1. Minichiello, A.; Hood, J.; Harkness, D. Bringing User Experience Design to Bear on STEM Education: A Narrative Literature Review. *J. STEM Educ. Res.* **2018**, *1*, 7–33. [CrossRef]
2. Sundt, A.; Davis, E. User personas as a shared lens for library UX. *Weave* **2017**, *1*. [CrossRef]
3. Baloglu, M. *A Comparison of Mathematics Anxiety and Statistics Anxiety in Relation to General Anxiety*; National Center for Research on Teacher Learning: East Lansing, MI, USA, 1999.
4. Ashcraft, M.H. Math anxiety: Personal, educational, and cognitive consequences. *Curr. Dir. Psychol. Sci.* **2002**, *11*, 181–185. [CrossRef]
5. Peker, M.; Ertekin, E. The relationship between mathematics teaching anxiety and mathematics anxiety. *New Educ. Rev.* **2011**, *23*, 213–226.
6. Turner, J.C.; Midgley, C.; Meyer, D.K.; Gheen, M.; Anderman, E.M.; Kang, Y.; Patrick, H. The classroom environment and students' reports of avoidance strategies in mathematics: A multimethod study. *J. Educ. Psychol.* **2002**, *94*, 88–106. [CrossRef]
7. Hembree, R. The nature, effects, and relief of mathematics anxiety. *J. Res. Math. Educ.* **1990**, *21*, 33–46. [CrossRef]
8. Guy, B.R. Movers, shakers, & everyone in between: Faculty personas surrounding active learning in the undergraduate STEM classroom. *Inq. Educ.* **2017**, *9*, 2.
9. Lilley, M.; Pyper, A.; Attwood, S. Understanding the Student Experience through the Use of Personas. *Innov. Teach. Learn. Inf. Comput. Sci.* **2012**, *11*, 4–13. [CrossRef]
10. Vorvoreanu, M.; Madhavan, K.; Kitkhachonkunlaphat, K.; Zhao, L. Designing for STEM Faculty: The Use of Personas for Evaluating and Improving Design. In Proceedings of the International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management, Montreal, Canada, 15 June 2016; pp. 369–380. [CrossRef]
11. Vyas, D.; De Groot, S.; Van Der Veer, G.C. Understanding the academic environments: Developing personas from field-studies. In Proceedings of the 13th European Conference on Cognitive Ergonomics: Trust and Control in Complex Socio-Technical Systems, Zurich, Switzerland, 20 September 2006; pp. 119–120. [CrossRef]
12. Merriam, S.B.; Tisdell, E.J. *Qualitative Research: A Guide to Design and Implementation*, 4th ed.; Jossy-Bass: San Francisco, CA, USA, 2015.
13. Inayat, M.F.; Hamid, S.N. Integrating new technologies and tools in teaching and learning of mathematics: An overview. *J. Comput. Math. Sci.* **2016**, *7*, 122–129.
14. Larkin, K.; Milford, T. Mathematics Apps—Stormy with the Weather Clearing: Using Cluster Analysis to Enhance App Use in Mathematics Classrooms. In *Using Mobile Technologies in the Teaching and Learning of Mathematics. Mathematics Education in the Digital Era*; Calder, N., Larkin, K., Sinclair, N., Eds.; Springer: Cham, Switzerland, 2018; Volume 12, pp. 11–30. [CrossRef]
15. Flood, V.J.; Shvarts, A.; Abrahamson, D. Teaching with embodied learning technologies for mathematics: Responsive teaching for embodied learning. *ZDM* **2020**, *52*, 1307–1331. [CrossRef]
16. U.S. Department of Education. Reimagining the Role of Technology in Education: 2017 National Education Technology Plan Update. Available online: https://tech.ed.gov/files/2017/01/NETP17.pdf (accessed on 12 June 2022).
17. Rechtsinformationssystem des Bundes. Gesamte Rechtsvorschrift für Lehrpläne—Allgemeinbildende höhere Schulen. Available online: https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10008568 (accessed on 12 June 2022). (In German).
18. Barana, A.; Fioravera, M.; Marchisio, M. Teacher training: A model for introducing innovative digital methodologies for learning Mathematics. In Proceedings of the 3rd International Conference on Higher Education Advances (HEAd'17), Valencia, Spain, 21–23 June 2017. [CrossRef]
19. Blazer, C. Strategies for Reducing Math Anxiety. Information Capsule. Volume 1102. Available online: https://files.eric.ed.gov/fulltext/ED536509.pdf (accessed on 12 June 2022).

20. Barana, A.; Brancaccio, A.; Conte, A.; Fissore, C.; Floris, F.; Marchisio, M.; Pardini, C. The Role of an Advanced Computing Environment in Teaching and Learning Mathematics through Problem Posing and Solving. In Proceedings of the 15th International Scientific Conference eLearning and Software for Education, Bucharest, Romania, 11–12 April 2019. [CrossRef]
21. Calder, N.; Murphy, C. Using Apps for Teaching and Learning Mathematics: A Socio-technological Assemblage. In Proceedings of the 41st Annual Conference of the Mathematics Education Research Group of Australasia, Auckland, New Zealand, 1–5 July 2018.
22. Mendoza, D.J.; Mendoza, D.I. Information and Communication Technologies as a Didactic Tool for the Construction of Meaningful Learning in the Area of Mathematics. *Int. Electron. J. Math. Educ.* **2018**, *13*, 261–271. [CrossRef]
23. Calder, N.; Larkin, K.; Sinclair, N. Mobile Technologies: How Might Using Mobile Technologies Reshape the Learning and Teaching of Mathematics? In *Using Mobile Technologies in the Teaching and Learning of Mathematics. Mathematics Education in the Digital Era*; Calder, N., Larkin, K., Sinclair, N., Eds.; Springer: Cham, Switzerland, 2018; Volume 12, pp. 1–7. [CrossRef]
24. Koehler, M.J.; Mishra, P.; Cain, W. What Is Technological Pedagogical Content Knowledge (TPACK)? *J. Educ.* **2013**, *193*, 13–19. [CrossRef]
25. Tatar, E.; Zengin, Y.; Kağızmanlı, T.B. What is the relationship between technology and mathematics teaching anxiety? *Educ. Technol. Soc.* **2015**, *18*, 67–76.
26. Clark, M. Mathematics as responsive tertiary education concerned with the needs of the students of the subject. *Int. J. Math. Educ. Sci. Technol.* **1979**, *10*, 581–585. [CrossRef]
27. Tsvigu, C.; Breiteig, T.; Persens, J.; Ndalichako, J. Promoting the learning of mathematics: On the use of learning styles in a distance education calculus course. In *Some Developments in Research in Science and Mathematics in Sub-Saharan Africa: Access, Relevance, Learning, Curriculum Research*, 1st ed.; Holtman, L., Julie, C., Mikalsen, Ø., Mtetwa, D., Ogunniyi, M., Eds.; African Minds: Somerset West, South Africa, 2008; pp. 133–156.
28. Calder, N.; Murphy, C. How might apps reshape the mathematical learning experience? In *Using Mobile Technologies in the Teaching and Learning of Mathematics. Mathematics Education in the Digital Era*; Calder, N., Larkin, K., Sinclair, N., Eds.; Springer: Cham, Switzerland, 2018; Volume 12, pp. 31–50. [CrossRef]
29. Minichiello, A.; Hood, J.; Harkness, D. Work in progress: Methodological considerations for constructing nontraditional student personas with scenarios from online forum usage data in calculus. In Proceedings of the 2017 ASEE Annual Conference & Exposition, Columbus, OH, USA, 24–28 June 2017. [CrossRef]
30. Van Rooij, S.W. Research-based Personas: Teaching Empathy in Professional Education. *Eff. Teach.* **2012**, *12*, 77–86.
31. Ferreira, B.; Silva, W.; Oliveira, E.; Conte, T. Designing Personas with Empathy Map. In Proceedings of the 27th International Conference on Software Engineering and Knowledge Engineering, Pittsburgh, PA, USA, 6–8 July 2015. [CrossRef]
32. Antle, A.N. Child-based personas: Need, ability and experience. *Cogn. Technol. Work* **2008**, *10*, 155–166. [CrossRef]
33. Maness, J.M.; Miaskiewicz, T.; Sumner, T. Using personas to understand the needs and goals of institutional repository users. *D Lib Mag.* **2008**, *14*. [CrossRef]
34. Miaskiewicz, T.; Sumner, T.; Kozar, K.A. A latent semantic analysis methodology for the identification and creation of personas. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Florence, Italy, 5–10 April 2008; pp. 1501–1510. [CrossRef]
35. Zaugg, H.; Rackham, S. Identification and development of patron personas for an academic library. *Perform. Meas. Metr.* **2016**, *17*, 124–133. [CrossRef]
36. Lewis, C.; Contrino, J. Making the Invisible Visible: Personas and Mental Models of Distance Education Library Users. *J. Libr. Inf. Serv. Distance Learn.* **2016**, *10*, 15–29. [CrossRef]
37. Cooper, A. *The Inmates are Running the Asylum: Why High-Tech Products Drive Us Crazy and How to Restore the Sanity*, 1st ed.; Sams: Indianapolis, IN, USA, 1999.
38. Volentine, R.; Whitson, L.; Tenopir, C. Portraits of success: Building personas from scholarly reading patterns. *Qual. Quant. Methods Libr.* **2017**, *2*, 1–8.
39. Glaser, B.G.; Strauss, A.L. *The Discovery of Grounded Theory: Strategies for Qualitative Research*, 3rd ed.; Aldine Transaction: New Brunswick, NJ, USA, 2008.
40. Strauss, A.L.; Corbin, J.M. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*, 1st ed.; Sage Publications: Newbury Park, CA, USA, 1990.
41. Statistik Austria. Schulbesuch. Available online: https://www.statistik.at/wcm/idc/idcplg?IdcService=GET_NATIVE_FILE&RevisionSelectionMethod=LatestReleased&dDocName=110063 (accessed on 24 May 2022). (In German)
42. Rechtsinformationssystem des Bundes. Gesamte Rechtsvorschrift für Prüfungsordnung AHS. Available online: https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20007845 (accessed on 6 January 2021). (In German)
43. ÖBV. Mathematik verstehen Oberstufe. Available online: https://www.oebv.at/lehrwerke/mathematik-verstehen-oberstufe (accessed on 23 April 2021). (In German)
44. Pädagogische Hochschule Wien. Fort- und Weiterbildungsangebot Sommersemester 2021. Available online: https://www.phwien.ac.at/files/VR_Lehre/HLG_und_FB_Angebot/FortbildungsAngebot/Fortbildungsangebot_SoS_21.pdf (accessed on 23 April 2021). (In German).

45. Bundesministerium für Bildung, Wissenschaft und Forschung. Modellschularbeiten und Leitfäden. Available online: https://www.bmbwf.gv.at/Themen/schule/schulpraxis/zentralmatura/srdp_ahs/mslf.html (accessed on 6 January 2021). (In German).
46. Bruneforth, M.; Lassnigg, L.; Vogtenhuber, S.; Schreiner, C.; Breit, S. *Nationaler Bildungsbericht Österreich 2015, Band 1*, 4th ed.; Leykam: Graz, Austria, 2016; Volume 1, (In German). [CrossRef]
47. Oberwimmer, K.; Vogtenhuber, S.; Lassnigg, L.; Schreiner, C. *Nationaler Bildungsbericht Österreich 2018, Band 1*, 4th ed.; Leykam: Graz, Austria, 2019; Volume 1, (In German). [CrossRef]
48. Statistik Austria. Schulen. Available online: https://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/bildung/schulen/index.html (accessed on 6 January 2021). (In German)
49. Statistik Austria. Schülerinnen und Schüler an Öffentlichen und Privaten Schulen. Available online: http://www.statistik.at/wcm/idc/idcplg?IdcService=GET_NATIVE_FILE&RevisionSelectionMethod=LatestReleased&dDocName=110065 (accessed on 24 May 2022). (In German)
50. Bacelo, A.; Roldán-Álvarez, D.; Martín, E. Turns vs consensus: Learning mathematics in multi-touch surfaces. *Int. J. Hum. Comput. Stud.* **2020**, *140*, 102431. [CrossRef]
51. Attard, C.; Calder, N.; Holmes, K.; Larkin, K.; Trenholm, S. Teaching and Learning Mathematics with Digital Technologies. In *Research in Mathematics Education in Australasia 2016–2019*, 1st ed.; Way, J., Attard, C., Anderson, J., Bobis, J., McMaster, H., Cartwright, K., Eds.; Springer: Singapore, 2020; pp. 319–347. [CrossRef]