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Pre-Service Teachers' Perceptions of Their Digital Competencies and Ways to Acquire Those through Their Studies and Self-Organized Learning

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Abstract: Rapid digitalization and the fast rise of generative AI tools pose fresh challenges to educational institutions, teachers, and students. Teachers of all subjects are expected to pass on key digital competencies along with subject-related knowledge to facilitate students' employability and navigation in a society characterized by the impact of digital technology in all areas of life. However, several studies have shown that there is still a lack of integration of digital competencies in teacher training programs. Hence, to add to these previous studies, this paper aims to find and explore strategies and measures to equip secondary-level pre-service teachers with digital competencies and support them in professionally promoting their students' digital skills. This happens by investigating what advanced pre-service teachers at a large European university miss and suggest changing to become more confident in promoting digital competencies at secondary school levels (K5–K12). In this context, the authors deepened a previously conducted university-wide survey among advanced secondary-level pre-service teachers through two focus groups to sharpen insights into challenges and good practices from the perspective of pre-service teachers. A thematic analysis of these focus groups confirmed the presumption that most pre-service teachers are keen on actively acquiring relevant digital competencies and gave insights into how they wish to have digital skills integrated into their studies. Additionally, it became evident that even though pre-service teachers can acquire several digital skills through self-study, they longed for collaboration and guidance to reach a professional level for "teaching" them to their students.

Keywords: digital competence; digital skills; pre-service teachers; teacher education; secondary education; focus group; thematic analysis; mixed methods

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1. Introduction

In a time when social and digital transformation is gaining momentum, educational institutions at all levels are called to equip learners with the transversal competencies needed to cope with current and upcoming challenges. One class of skills, whose importance became increasingly evident due to the SARS-CoV-19 pandemic and its restrictions on direct social contact, is digital skills. There is agreement and evidence that these skills significantly contribute to students' study success [1]. Such indications point to the fact that educational institutions are urgently called upon to promote digital competencies. While this need applies universally, it is particularly crucial for institutions that offer curricula for teacher education, such as, in our case, the University of Vienna in cooperation with the Northeastern University Colleges of Teacher Education in Austria. This is why the authors chose to dedicate this research contribution to shedding light on the status, current role, and necessary further development of teaching digital competencies within the teacher education program as perceived by advanced pre-service teachers at the authors' institution. By advanced pre-service teachers, we mean students of the teacher training program who have completed at least 180 ECTS (European Credit Transfer System) units of the bachelor's

program or are enrolled in the master's program of teacher education. Moreover, the assumed wider validity of our findings is investigated by connecting respective findings to other published research on the development of pre-service teachers' digital competencies. Thus, the pre-service teachers' perceptions of their digital competencies should feed into the objective of finding and exploring strategies and measures to equip secondary-level pre-service teachers with these competencies.

1.1. Thematic and Contextual Background

The first important step towards finding solutions for the mentioned challenges and for integrating digital competencies into the curriculum is to agree on what we mean by digital competencies. The definition of digital competencies is by no means trivial, as there have been several efforts to define them. Different authors have used various terms such as digital skills, digital competencies, or digital literacy, which all have slightly different meanings but, overall, do strongly overlap.

Ferrari [2], for example, describes digital competencies as "the set of knowledge, skills, attitudes, abilities, strategies, and awareness that are required when using ICT and digital media to perform tasks, solve problems, communicate, manage information, collaborate, create and share content, and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning, and socialising".

Aviram [3] describes digital literacy as "a combination of technical-procedural, cognitive, and emotional-social skills". Van Dijk [4] explains digital skills as something that goes beyond the sole operation of computers and network connections. According to him, digital skills include the ability "to search, select, process and apply information from a superabundance of sources and the ability to strategically use this information to improve one's position in society". Overall, we can conclude that no matter how different researchers refer to that specific ability/skill/competence, it goes far beyond the mere operation of electronic devices. Moreover, as Mishra and Koehler [5] established in their TPACK (Technological, Pedagogical, Content Knowledge) model, the intersections between the three domains of knowledge need to be understood and considered in any educational endeavor addressing the digital sphere [6].

In this study, the terms skills and competencies are used interchangeably with "skills" focusing more on abilities and "competencies" being the more encompassing term subsuming knowledge, skills, and attitudes. In finding a suitable definition, our team agreed on the following: "By digital skills, we mean all the skills and abilities necessary in the digital era to participate responsibly in social and professional life, such as the informed acquisition of information and the responsible use of digital media, tools, and platforms." This definition already underlays a university-wide survey whose detailed analysis has been prepared for publication [7], while a few selected findings were published in a conference paper [8].

Multiple institutions and organizations such as UNESCO and the EU Commission have developed elaborate frameworks for implementing digital competencies to cope with upcoming challenges on an international scale. DigComp 2.2, for example, describes the skills and competencies necessary for becoming a digital citizen with learning, working, and participating in society. The framework addresses digital competencies in the five areas: (1) information and data literacy, (2) communication and collaboration, (3) digital content creation, (4) safety, and (5) problem-solving [9]. The framework is intended to be specialized via national frameworks capturing the specifics of individual nations. In Austria, this framework is specialized by the DigComp 2.3 AT [10]. In addition, DigCompEdu, the European Framework for the Digital Competence of Educators, addresses educators at all levels of education. It specifies 22 competencies organized in six areas to describe "how digital technologies can be used to enhance and innovate education and training" [11]. However, even though frameworks aim to provide a technology-neutral understanding of digital competencies that can be adapted to various digital technologies as they evolve, the

rise of powerful AI tools is going to necessitate further adaptations of digital competence frameworks and required competencies to use such tools responsibly and effectively [12].

Despite all the crucial initiatives of constructing adaptable frameworks, they have not (yet) been effectively integrated into teacher training. An analysis of teacher training programs [13] indicated that there was even less coverage of digital content in recent years. An effective inclusion of ICT content and skills to promote digital competencies was missing in the curricula.

To provide the context of the teacher training program at the University of Vienna, it should be noted that students in the teacher training program must complete a bachelor's and a master's program. The bachelor's program consists of eight semesters and the master's program takes four semesters. Apart from studying the 'general basics of educational science', teacher candidates must choose a combination of two subjects out of twenty-seven available subjects or combine one subject with inclusive pedagogy. Optionally, an expansion of their studies by a third subject is possible.

1.2. Research Objectives and Research Questions

The overall objective is to find and explore strategies and measures to equip secondary-level pre-service teachers with digital competencies and support them in professionally promoting their students' digital skills. Concretely, our primary goals are to find out what matters most to pre-service teachers in the era of digital transformation. The findings are intended to guide the development of guidelines and good practices for a teacher training curriculum that fits pre-service teachers' needs and effectively qualifies graduates to pass on digital skills to learners at levels K5–K12, across school subjects. As such, this paper is relevant to researchers in education, computing, and media science and educational technologies, as well as curriculum designers, teacher educators, teachers, and policymakers—in brief, all those aiming to co-frame the digital transformation in learning.

The current paper answers the following research questions:

RQ1: Which associations/reactions/suggestions do pre-service teachers with a deep interest in professionally promoting digital skills have when presented with selected results of a university-wide survey on pre-service teachers' digital skills in the context of the teacher education curriculum?

RQ2: Which insights follow from pre-service teachers' perspectives and which concrete measures and necessary further steps can be derived?

1.3. Theoretical Framework

While this research aligns with the social constructivist tradition [14], it also strongly connects to the following three theories: First, Ryan and Deci's Self-Determination Theory (SDT) [15] explains the need to develop digital competence along all three dimensions of needs distinguished by SDT: competence, relatedness, and autonomy. Teachers, as well as students, strive for competence in the digital world to participate in it safely and effectively. As social networks and virtual communication are key to cyberspace, people cannot accomplish much without interacting with others, bringing the dimension of relatedness into play. Finally, as in the real world, they strive for autonomy and self-direction when participating in the virtual world that we consider part of the current "reality".

Second, collaborative learning as proposed by Bandura [16] and further elaborated by Johnson and Johnson [17] comes in handy for providing multiple and creative perspectives for problem-solving, and for dealing with challenges and hurdles collaboratively to reduce frustration [18]. Students, and teachers alike, can get lost in the abstract, technical, and complex cyberspace, such that peer support and collaborative effort can accelerate progress and boost motivation [19].

Third, the current research is related to humanistic student-centered learning theories as originally promoted by Rogers [20,21], who involved learners (both students and teachers) as active participants in their learning while providing an open, constructive atmosphere. Several followers [15,22–24] carried forward student-centered learning in the

new millennium, often enhancing it with technology [25–29]. Since activities in cyberspace often lead to unexpected results, the capacities of reflective practitioners [30] who deliberate on their actions significantly contribute to learning in active, student-centered settings. At its best, reflection of experiences would proceed in a student-centered atmosphere, building the bridge to collaborative learning and SDT.

1.4. Related Work

Following a qualitative research approach, Lameras and Moumotzis [31] conducted studies about required competencies from a teacher's point of view. The researchers discerned the following six digital competencies with additional sub-competencies teachers perceive as especially useful for "teaching and learning with technology": (1) production and presentation of digital content, (2) acquisition of information and data and related media literacy, (3) development of digital skills while teaching, (4) proficiency with digital learning gadgets, (5) development of digital soft skills, and (6) appropriate mediation of digital competencies to students [31]. Moreover, as early as 2014, a Norwegian research team found that various factors including learning experience, the way theory and practice are linked, reflection, access to resources and support, and collaboration in learning influence the development of digital competencies among young teachers and pre-service teachers [32]. All these factors are highly relevant in the authors' current study, which delves deeper into some of them and accentuates the relationship between the curriculum and self-regulated learning of digital competencies. In addition, Brevik et al. [33] found that pre-service teachers face different challenges while developing digital competencies including the uncertainty about integrating different knowledge types into their teaching and learning. Teachers face a fundamental conflict between the desire to teach and the need to adapt to rapidly evolving Information and Communication Technology (ICT). All those research insights underpin the difficulty in effectively integrating highly relevant digital competencies into teacher training.

Complementary to our study, Farjon et al. [34] studied pre-service teachers' technology integration at the beginning of their "teacher education program, since beginning teachers indicated that they do not feel fully prepared to integrate technology effectively in the classroom". Intriguingly, out of the four factors examined, attitudes and beliefs toward technology were found to have the strongest influence on technology integration. Similarly, Suelves et al. [35] stated that "the analysis of the results obtained in previous research shows limitations in the specific training in ICT received in general education degrees as well as the tendency to develop this competence from a transversal perspective". As a response, the authors presented and analyzed a successful classroom experience involving the integration of ICT across different subjects in the Master's Degree in Secondary Education at the University of Valencia. This good practice illustrates and motivates the feasibility of transversally developing digital competencies in any subject.

Wilson et al. [36] studied the effects of teacher education courses for technology integration (TECTI) on pre-service teachers' practical and conceptual knowledge relevant to technology-integrated education in PK12 classrooms. Having searched five academic databases, the authors performed a meta-analysis that comprised data from 3271 pre-service teachers. While practical and conceptual knowledge had a statistically significant positive effect size, none of the eight course-design features examined such as coaching, hands-on learning, and reflection were statistically significant. This can be explained by the observation that technology integration in PK12 classrooms happens in several forms, such that one design feature that dominates others could not be singled out. Still, Oguguo et al. [37], who analyzed tools such as Moodle, MSTeams, Zoom, and Google Classroom during COVID-19 times, found the use of online learning applications in classroom instruction and continuous assessment to be low.

Recently, Bernsteiner et al. [38] conducted a survey on the use of digital media in teacher education in the STEM (Science, Technology, Engineering, and Mathematics) disciplines, based on previous studies by Vogelsang et al. [39] and Stinken-Rösner et al. [40]. These studies inspired the current contribution that extends the previous ones in two

dimensions: moving from STEM to all fields of teacher education and surveying the use of digital media to study secondary pre-service teachers' digital competencies. Another study grounded in the STEM model analyzed knowledge, skills, and attitudes in the context of digital technologies and metacognition [41].

Lastly, a recent systematic literature review on ECTs' (early-career teachers') digital competency development [42] provides a strong foundation for relating our findings to those reported in the international literature. This is because our research subjects were advanced teacher education students, many of whom were already teaching at schools, and thus qualified as ECTs. Hence, the subjects of Masoumi and Naroozi [42] and those of the current study overlap, inviting a thorough discussion of the respective results (see Section 4).

Masoumi and Naroozi [42] chose 25 relevant publications for their systematic literature review to explore the challenges early-career teachers (ECTs) face in integrating digital technologies into their teaching activities. As a prerequisite, ECTs would need to develop their professional digital competence (PDC), also known as digital literacy or digital competence in education. The authors confirmed the widespread phenomenon of ECTs not feeling sufficiently prepared to integrate digital technologies into their teaching activities. The literature suggests that only a few ECTs can create digital learner-centered learning environments. Moreover, by investigating ECTs' PDC, Masoumi and Naroozi [42] found collective evidence on how ECTs' PDC can be developed and identified contributing factors. Among the key factors for ECTs developing their PDC were the personal active exploration of ECTs, taking advantage of development opportunities, being guided by a mentor, and the PDC being interwoven with ECTs' overall professional development. The research also identified factors contributing to the ECTs' digital competence development, including institutional culture, availability and accessibility of resources, and technical and pedagogical support. Hindering factors, such as the heavy workload of ECTs, especially with new tasks and duties were also spotted. Masoumi and Naroozi [42] concluded that several measures should be considered to support ECTs' development of PDC, such as providing targeted and continuous training by institutions, encouraging collaboration between ECTs and experienced colleagues to promote knowledge sharing, or changing institutions' policies to promote digital literacy goals.

2. Materials and Methods

2.1. Research Context

Our main research interest is to gain insight into pre-service teachers' perceptions of their digital competencies and ways to acquire them. In this context, this paper aims to find and explore strategies and measures to equip secondary-level pre-service teachers with digital competencies and support them in professionally promoting their students' digital skills.

To approach this objective, we embarked on a sequential, explanatory, pragmatically motivated mixed-method approach [43] consisting of a university-wide online survey sent to 4054 pre-service teachers and a series of follow-up focus groups [44]. The first round of focus group discussions consisted of pre-service teachers studying different subjects and will be elaborated on in detail in this paper. The focus groups were held to complement the findings from the university-wide online survey conducted in 2022 (for selected initial results, see [8]) with a more vivid, semi-structured face-to-face elaboration and thus help us to gain deeper insight into what effectively supports pre-service teachers to become digitally professional and self-confident.

Figure 1 describes the overall procedure of the mixed-method approach, whereby the white section addressing the focus groups is the one that is considered in this paper. The grey section was briefly presented in [8] and is being addressed comprehensively in an upcoming paper [7]. Nevertheless, it is briefly referred to in the current paper since the outcomes of the survey significantly influenced the questions asked in the focus groups and their thematic focus.

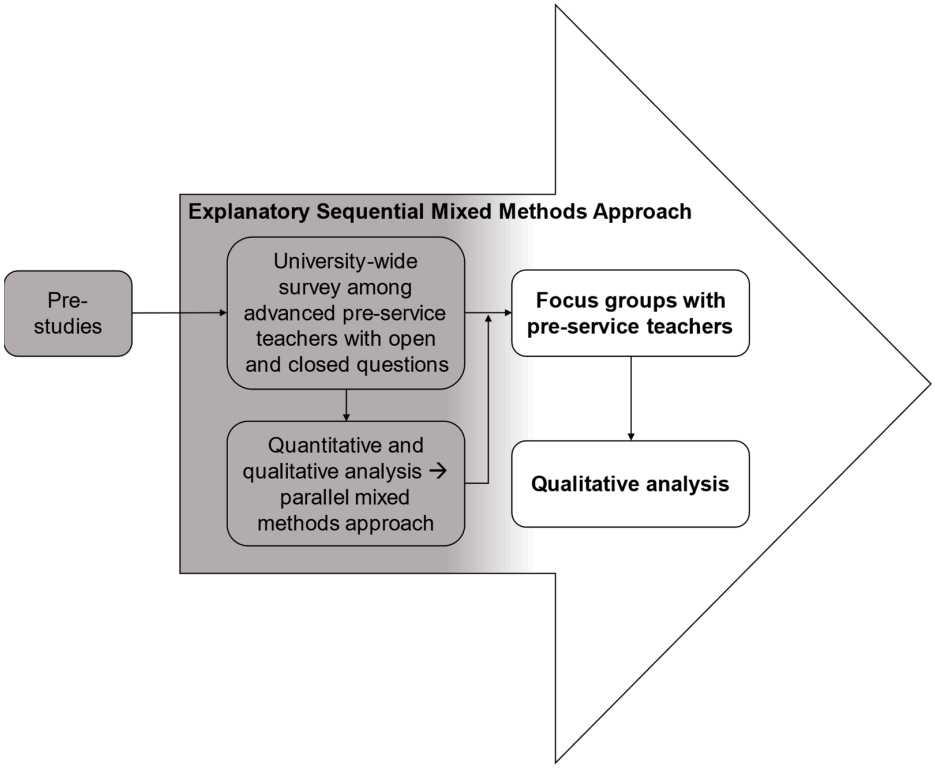


Figure 1. Procedure of mixed-method approach with focus groups (white part) as the explanatory part and focus in the current paper.

2.2. Preliminaries from the Survey as Background Information for the Focus Groups

From the university-wide online survey among advanced pre-service teachers who had acquired at least 180 ECTS (1 ECTS amounts to 25 h of student workload) [7,8], it became evident that only about half of the study participants (49%) reported that they felt sufficiently prepared through their studies to pass on digital competencies to their students. Moreover, the study provided evidence that 72% of the pre-service teachers acquired 75% or more of all digital competencies they possessed in a self-organized way. Although developing digital competencies through self-learning appears feasible, pre-service teachers still desire more support in shaping digital competencies during their academic studies. One of the main insights gained through the survey was that, even though pre-service teachers tend to acquire a significant share of their digital skills in self-study, they wish for more depth and guidance regarding digital competencies and ways to teach them. In particular, 90% of the pre-service teachers would desire more coverage of digital competencies in the 'general basics of educational science' part of the curriculum [8], a fact that resonates with results from [13]. Pre-service teachers need to select just one out of multiple seminars, whereby many of them—not all covering digital competencies—might be valuable for their future teaching. Consequently, gaps in the digital proficiency of pre-service teachers are evident, and the challenge is to fill them in a way that grants all pre-service teachers equal opportunities to develop their digital competencies during their studies. This challenge arises at a time when AI-powered generative tools, such as ChatGPT, are becoming increasingly prominent, with an anticipated significant impact on various aspects of human behavior.

2.3. Participants in the Focus Groups

The research subjects of the first focus group consisted of three pre-service teachers who had responded to the online survey at the University of Vienna and stated availability for further questions. All of them were contacted by email and accepted the invitation to

the focus group discussion. All three were female and studied different subjects. Two were already in the master's program and one was an advanced bachelor's degree student.

One of the researchers was also a pre-service teacher who had participated in the qualitative analysis of the survey; for shorter reference, we call her Jessica in this paper. By being immersed in research as well as teacher education, she acted as a mediator between the pre-service-teacher participants and the three other researchers. Of the latter, two were males and were employed as part-time secondary teachers and part-time researchers at the Faculty of Computer Science; for shorter reference, we call them Peter (a recent graduate of teacher education at the University of Vienna) and Joseph (a post-doc researcher). The third researcher was a female professor and teacher educator at the Faculty of Computer Science and Centre of Teacher Education; we refer to her as Susan in this paper.

The three participants and the four researchers met in person to inspect and discuss the findings from the university-wide survey. The meeting was designed in a workshop format and took place in one of the seminar rooms at the Faculty of Computer Science.

About one year later, a second focus group meeting with different participants was held to discuss the results and implications of the university-wide survey with seven master's degree pre-service teachers in the teacher education program. All seven had in common that one of their subjects was Computer Science and that they were currently enrolled in a course focusing on research methods into which the focus group was integrated. However, their second or third subjects differed. Also, four of them were already employed at secondary schools, and thus would also be referred to as early-career teachers. In this second focus group, three participants were female and four were male. Five of them were already teaching in schools. The meeting was moderated by Susan and assisted by Jessica.

We decided to conduct the second focus group with pre-service teachers whose first subject was Computer Science, as we were interested in whether their perceptions of the mediation of digital skills in the teacher education program would differ from the perceptions of the other pre-service teachers.

2.4. Research Instruments

2.4.1. Procedure of Data Collection

In the focus groups, the researchers presented pre-selected findings from the online survey and asked the participants to interpret the results and share their ideas, opinions, and thoughts on the data displayed. We created a workshop-like atmosphere, where ideas were developed with and by the pre-service teachers while the researchers listened actively using paraphrasing, reflecting, and summarizing responses for clarification and checking their understanding. The meetings were truly interactive with dialogue being interspersed with the presented slides.

The first meeting was recorded with the participants' approval. The students were informed about the data collection and data analysis procedure and gave their informed consent. Subsequently, the recording was transcribed to facilitate the subsequent thematic analysis. The transcribed corpus consisted of 11,578 words and yielded 58 meaningful statements. During the second focus group meeting, Susan and Jessica independently took notes and each of them drafted a protocol. The participants of the second focus group were also informed about the data collection and analysis procedure and gave their informed consent. After that, they compared their protocols and merged their drafts into one protocol. At a later stage, the protocol was shown to the participants again in a Zoom meeting to allow them to check and—if needed—reformulate their ideas, clarify comprehension issues, or expand on their previous statements. The Zoom meeting was audio-recorded with their consent. This recording was then automatically transcribed by using the AI Tool MeetGeek. The transcript was checked and corrected. It consisted of 6291 words, yielding 57 meaningful statements.

We decided to hold the second focus group meeting at a later stage as we were keen to find out whether something had changed over time and whether the change from pure online

lectures during the COVID-19 pandemic to hybrid or face-to-face classes had an impact on the perceived importance of addressing digital skills in the teacher education program.

2.4.2. Procedure of Data Analysis

We decided to carry out a thematic analysis since it seemed most effective to support the explanatory component of the mixed-method approach, as it formed a flexible basis for identifying, analyzing, organizing, describing, reporting, and discussing themes found within the data collected [45]. Also, considering time constraints, a selective analysis of themes related to the research questions was more feasible than a fine-grained qualitative content analysis [46] of the whole corpus. The meaningful statements of each of the two focus groups were used as units of analysis. To increase qualitative quality [47], the credibility and dependability of the qualitative study [45] in particular, activities such as prolonged engagement, data collection triangulation, and researcher triangulation were practiced and are summarized in the preceding and following subsections.

For the first focus group, the themes were introduced deductively. They are based on the results of the online survey. Those themes were then complemented by themes and sub-themes that inductively emerged while reading the focus group's transcript [44]. This inductive complementation proceeded as follows: Susan and Jessica read through the transcript multiple times. Then, Jessica provided a proposal about themes and subthemes she identified. Susan compared her suggestions with Jessica's, and in an intensive dialogue, they looked for interconnections until they agreed on six themes and associated subthemes. For a better overview, the themes and their subthemes were organized in an Excel sheet and the transcript was coded. In a further coordination meeting, the six themes were reduced to five by merging the themes "good practices" and "lack of competencies of lecturers and solutions" into the new theme "good practices and overcoming problems". After that, Jessica and Susan refined the definition of each theme and selected prototypical example statements for each theme. Finally, Jessica fine-tuned the assignment of statements to the most suitable theme and Susan and Peter fully agreed to it.

For the second focus group meeting, we analyzed the transcribed protocol of the Zoom meeting as follows: After reading the protocol, Susan and Jessica independently assigned meaningful statements to the themes of the first focus group. Subsequently, they compared and discussed their results in a meeting, aiming to increase credibility [46] and confirmability [44]. The five themes that were defined during the analysis of the first focus group proved to cover all meaningful statements of the second focus group very well, such that Jessica and Susan used these themes for assigning the meaningful statements of the second focus group. In a follow-up meeting, the two researchers discussed their assignments and added some well-fitting statements from the second focus group as prototypical examples of the five themes in Table 1.

Table 1. Themes of the thematic analysis and their respective frequencies (#), which reflect the pre-service teachers' perceived relevance of a theme.

Definition	#	Illustrative Statements from the Focus Groups' Participants
Theme "Relevance and Status Quo"		
Participants' attitudes toward and proficiency regarding digital skills	12	"At both [schools], they have smartboards, and therefore it does make sense if someone feels overwhelmed with them if they haven't worked with them ever before". "To know how to work with digital devices is just the same as knowing how to effectively work with projectors, laptops, etc., the smartboard counts to that group". "I know that [Moodle] only from the user's perspective!" "Digital skills are very relevant as they are necessary in the daily work as a teacher". At university, you only learn things that are not practical for the life of a teacher. We do know how the programs work, however, there is a lack of courses that teach you how to pass on this knowledge".

Table 1. *Cont.*

Definition	#	Illustrative Statements from the Focus Groups' Participants
Theme "Self-organized learning of digital skills"		
Participants' experience with and perceived limitations of self-organized learning of digital competencies	12	"Digital tools may have been touched upon in courses, and may have been used, but the right occupation with them, the acquisition itself happens in a self-organized way". "In a group, it's just more fun to exchange ideas and talk about them, then the students and teachers have more motivation to get involved". "Of course, I can teach myself how to use a tool, however, I will never know for sure, whether I use it properly, or whether there is more to know than the stage I know. Moreover, it would be good to know how to mediate this self-acquired knowledge. One would simply feel more confident and prepared".
Theme "Resources for supporting the acquisition of digital skills"		
Any resources (materials, tools, devices) participants considered important for acquiring digital skills and teaching them at secondary level	16	"Longer access to literature would certainly not be bad, also in terms of access to other resources, including other literature [i.e., beyond that used in some course]". "Maybe it even needs professionally created [tutorial] videos". "Especially, one should learn how to organize oneself with the help of digital tools". "It would be desirable to have something like a toolkit, where I have several tools ready to use in the classroom. One would be more prepared and well-equipped to use digital tools if one had been trained in these tools".
Theme "Good practices and overcoming problems"		
Participants' perspectives on practices and means that proved helpful for the acquisition of digital skills during the teacher educationprogramincluding any ideas on how to overcome obstacles	44	"I think it [learning digital competencies] goes well in lectures that more or less everyone attends, and also in seminars, where you are told which tools are available [. . .] and a list is issued, which tools are where. Then, for example, the programs are explored in groups and then explained to the others like a presentation, where there is also room for discussion and where you can ask questions. But there might also be a need for freedom, so you don't have to attend every session, but, like every second session, you meet and then discuss what you learned in self-study last week". "Centralized seminars, which are done via digital mediation programs, where students can click through [. . .] without the need for a 'real' teacher because I don't know many people who could teach it". "The knowledge that you gained beforehand in the lecture is then again needed in the follow-up seminar, which means you could then link it if you say, okay, teach it to yourself digitally beforehand using the tools without the need for everyone being back in the lecture hall and afterward you do a seminar that goes into more depth".
Theme "Others"		
Statements not related to the research questions	31	-

During the assigning process, we noticed that many statements of the two focus groups were considered to be categorized under the theme "Others". The reason is that pre-service teachers were eager to share their experiences in their overall teacher training program, such as the overload of theory in its initial phase or the lack of practicums. We wanted to grant them space for sharing that; however, those utterances were not relevant to our current research questions. To stay focused in this paper, we decided to refrain from further elaborating on the category "Others".

As no new themes emerged from the second focus group and participants' statements tended to go in the same direction as those from the first focus group, we assumed that data saturation had been reached [44] and decided to end the series of focus groups with pre-service teachers.

3. Results

In the following, each of the four themes identified in the thematic analysis of the focus groups will be described in greater detail (five themes were identified including a category "Other", which we will not further elaborate on in this paper). We decided to attend to the themes in the order of how they occurred during the focus groups.

3.1. Relevance and Status Quo

For warming up in the group, we asked the participants, "What is your motivation to participate in this focus group?" This question was supplemented with follow-up questions introducing the theme "relevance of digital skills and the status quo". The following sub-themes, which were derived from the questions asked in the first focus group, emerged:

- Relevance of digital competencies in teacher education and justification;
- Experiences with digital competencies in the teachers' program.

In the focus groups, the relevance of digital competencies for pre-service teachers became apparent through some telling examples. One pre-service teacher remarked, "I was at a job interview in two schools, and at both [schools], they have smartboards. Therefore, it makes sense to me that someone feels overwhelmed with them if they haven't ever worked with a smartboard before". A participant of the second focus group suggested integrating the information and practical experience with smartboards into the practicum that every student has to attend at least two times during their study (in both subjects once).

Other examples of relevant digital competencies that would be useful regardless of whether the instruction is carried out face-to-face or in a distant learning mode were the set-up (not only use) of a Moodle™ course as a teacher, and the knowledge and application of a broad range of functionalities available in MSTeams™.

3.2. Self-Organized Learning of Digital Skills

The next focal theme in the group evolved around self-organized learning of digital skills. This focal theme concerns the following sub-themes:

- The degree to which digital skills can be self-organized and the point at which support or instruction is needed;
- The perceived limitations and obstacles of the self-learning mode;
- Examples of how self-organized learning of digital skills can be supported.

In the survey [7,8], pre-service teachers were asked what percentage of their digital skills they had acquired through their studies and how many in a self-organized manner. Figure 2 presents the results.

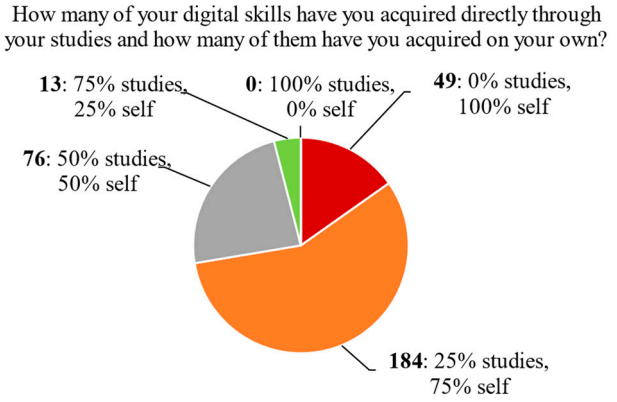


Figure 2. Percentage of digital skills that were acquired through studies ("% studies") versus in a self-organized way ("% self"). Numbers in bold represent the absolute number of pre-service teachers who chose the percentage ratios given on the right-hand side of the number.

We presented these results to the focus group participants and were most curious about their comments. In agreement with the survey's outcome, one pre-service teacher remarked, "Digital tools may have been touched upon in courses and may have been used, but when you find yourself in a teaching situation, the acquisition happens in a self-organized way". Susan asked the participants, "Why should one teach digital skills if they can be acquired in a self-organized manner anyway? However, there may be a limit somewhere. There might be something that doesn't work in that way. Something, where it is necessary to have it taught by someone". A pre-service teacher responded pointedly, "I just thought like for example if I'm doing much teaching with traditional methods, then maybe I don't even know that Padlet, for instance, makes teaching so much easier. When doing a brainstorming activity in class, there is no need for everyone to come to the board, they can all write their thoughts online in the Padlet. So, if I have never seen this tool in practice, it never occurs to me that there would be such a thing". Joseph

paraphrased the response saying: "so that you know which tools that are practical for teaching exist!". Another student added that, "The motivation is higher" and deepened her argument with "In a group, it's just more fun to exchange ideas and talk about them, and then the pre-service teachers and teachers have more motivation to get involved".

A pre-service teacher stated that, when she was asked to use MSTeams™ for teaching during an internship, she experienced troubles, as she had only used MSTeams as a participant, but had never organized or moderated a meeting. She complained that merely being invited to the MSTeams™ sessions does not allow one to know what functionalities MSTeams™ provides and in which ways it can support one's teaching.

Since the Moodle™ learning platform is frequently used at the university and in schools, Joseph asked, "What about Moodle? What is your experience with working with it? Is that taught in the teacher training courses?". A pre-service teacher responded, "No, only as a user, never from the other side, I have no idea how that works or anything".

When asked how to support self-organized learning, a pre-service teacher responded, "Yes, definitely tutorials, I mean, I'm already used to watching all Adobe stuff on YouTube, but I also need something for my students. How can you teach this stuff to them even more easily? That [i.e., videos for students] would be necessary!".

Important for university administration and consistent with the survey results, pre-service teachers unanimously requested to retain access to the literature and course material after graduation.

3.3. Resources for Supporting the Acquisition of Digital Skills

The third focal theme emerged in connection with necessary resources for supporting the acquisition of digital skills and means to pass them on to secondary-level learners. The participants discussed the following sub-themes:

- Materials and resources for general education and specific subjects;
- Designing of materials and resources and responsibility for their creation;
- Organization of these resources for easy access and adaption.

The online survey regarding the question of which resources pre-service teachers would find most helpful for advancing their own and their students' digital skills delivered the following results: 84 out of 123 statements (68.3%) concerned resources that could be found and directly used in the classroom, while 30 statements (24.4%) asked for resources that would support the self-learning of digital skills. Nine statements (7.3%) were general comments. Based on these findings, Jessica asked the participants, "What reasons could there be, why resources for 'digital basic education' are so frequently requested?" One of the pre-service-teachers immediately responded, "I think because there is a lot of catching up to do, i.e., from the teachers or the pre-service teachers who do not feel prepared to work something out on their own". Another student added, "To save time!".

Further input revolved around the (non-)availability and adequacy of tutorial videos in general and for specific subjects. A pre-service teacher shared, "[...] for basic things, DIY things, and handicraft things, it's difficult to find really good videos for young people. You might even need videos that have been produced professionally". Joseph paraphrased that with, "Videos that are didactically prepared, you mean". He found resonance with Peter, who remarked that he had searched for tutorials dealing with video cuts and that they were on a quite high level—needing lots of time to deal with the tool to familiarize oneself with it. A pre-service teacher responded (in the context of producing suitable videos), "[...] and that is also extremely time-consuming and expensive! So, getting someone to film the whole thing and, well, ... as a teacher, I couldn't do it for my students, that's not possible".

3.4. Good Practices and Overcoming Problems

Finally, the last theme—and the one that attracted by far the most statements during the focus group—concerned "good practices and problems", which deals with fruitful, effective conveyance of digital skills during the teacher education curriculum. Subthemes that came up included the following:

- Content and resources that would be particularly relevant;
- Factors to be considered when teaching digital competencies;
- Obstacles/barriers that need to be considered and how these could be overcome;
- Good practices in the teachers' training program that successfully promote (digital) competencies.

Concerning tools, one pre-service teacher pointed out that the digital class register had not been taught at all but would have been useful as it is used in schools. The participants of the focus groups agreed that gaining hands-on experience with administrative software tools that support a teacher's daily work would be highly useful. In this context, participants of the second focus group complained about their mentors, who are supposed to introduce them to administrative software used at the respective school, often lack the time and resources to do so.

Another pre-service teacher mentioned that concerning the identification of fake news, it would be a good idea to teach students some basic skills in programs like GIMP or Photoshop to demonstrate and let them directly experience how much manipulation of visuals is possible solely through editing. More generally, applications like Microsoft Excel, Padlet, Mentimeter, and Kahoot were mentioned as useful for various engaging tasks.

When asked about obstacles/barriers and how these could be overcome, the pre-service teachers pointed out the lack of practical exercises and particularly the lack of knowledge/know-how of tools and 21st-century skills on the side of some teacher educators. At the same time, the pre-service teachers were quick and creative with constructive ideas, such as suggesting some courses with practical tasks where pre-service teachers work in small teams ("expert teams") and collaborate to become experts on a specific tool or topic. Afterward, they would introduce the tool in which they became experts and illustrate how the tool can be used in different teaching and learning scenarios instead of just presenting it superficially. Ideally, the participating pre-service teachers would get the chance to try to solve meaningful tasks with the tool by themselves, and the teacher educators would act as moderators of the student-team-led sessions.

It was also pointed out that the usual teaching formats of university courses might not be ideal for teaching digital competencies. One of the pre-service teachers mentioned that she had helped to develop courses for a project called 'Experimental Lab bits and bites.' The idea is not to have big lectures but many small ones, where each course covers specific topics. The pre-service teachers must combine several small modules called "bits" (the mini-courses) to pass the overall course. The mini-courses could be chosen based on interest or to close knowledge gaps. This mode should give the pre-service teachers more control over what they learn and keep their interest high since there is never an "overdose" of a topic.

3.5. Differences between the Two Focus Groups

Although no new themes appeared in the second focus group, we noticed three interesting developments in the second group that took place one year after the initial one. First, pre-service teachers mentioned a few additional courses that considered and implemented the need for digital activities. For instance, pre-service teachers were required to give presentations online and were given guidelines for their online participation. Pre-service teachers found that helpful but insufficient. The second difference is ascribed to the fact that the participants of the second focus group had in common that one of their subjects was Computer Science. They struggled even more with the hurdle that schools tended to lack appropriate, well-functioning equipment they would appreciate for passing on digital skills. Third, (pre-service) teachers of Computer Science complained about a severe lack of educational resources for imparting digital skills, calling for a collaborative effort to overcome this hurdle. There was no sign of any decrease in the relevance or importance of digital skills from the first to the second focus group.

4. Discussion

4.1. Discussion and Interpretations of Key Findings

In this subsection, we highlight findings that deserve special attention.

The smartboard is an example illustrating the limits of self-regulated learning.

One pre-service teacher illustrated a blind spot—the skilled use of smartboards (interactive whiteboards) that tend to be used in schools much more than at the university. We interpret this example as a special case of the skilled handling of digital devices used at schools and hence should be familiar to pre-service teachers and teacher educators alike. This indicates demands on both sides, the availability of such devices and skills for handling them professionally that can hardly be acquired on one's own.

The smartboard is an example illustrating that change is slow or missing.

Interestingly, Rokenes and Krumsvik [19] already mentioned "interactive whiteboards" and found that there was "an acute absence of studies on preparing student teachers in using interactive whiteboards for the secondary school grade level". Not much has changed within the last decade. One reason may be the fact that a joined, orchestrated effort from several stakeholders, including curriculum designers, teacher educators, university leadership, school mentors, administrators, IT services, the legal department, and politics, is needed for systematic change in preparing pre-service teachers for handling digital resources at secondary schools.

Pure usage of digital tools during courses does not suffice; digital skills deserve to be articulated and pursued as learning outcomes.

Based on the pre-service teachers' critique regarding having used Moodle™ or MSTeams™ only from a student's perspective, we deduce that pre-service teachers must receive the opportunity to use selected tools in the role of teachers—as architects of learning sequences—not just as 'consumers'. Also, student-centered, collaborative learning strategies as described in Hoidn and Klemenčič's edited book {22] and elaborated upon by Motschnig-Pitrik and Standl [23] such as sparking each other and providing as well as receiving peer feedback are called for. Most digital skills need to be acquired by performing meaningful tasks with them, not just superficial ones. Consequently, courses should make their aspired digital skills explicit and coordinate them across courses of the teacher education curricula.

Pre-service teachers long for more guidance and resources.

Pre-service teachers felt self-confident to acquire basic digital skills on their own by studying tutorials, videos, and resources they found on the Internet. However, in the pre-service teachers' view, these do not fully keep up with a guided, didactically sound exposure to digital competencies, complemented by reflection [30], peer discussion, and peer learning [17,42]. This is because searching for appropriate resources and finding out everything one needs to know can be highly time-consuming as well as tedious and does not always deliver the most appropriate tools or practices needed to solve specific tasks. The wish for guidance corroborates Vygotsky's concept of the Zone of Proximal Development [48] revisited in Section 4.3 below. In addition, pre-service teachers expressed a desire for more resources for digital basic education. Optimistically the advent of generative AI-driven tools may provide ample information and resources; however, the need for critical thinking, open discourse, and reflection to validate and adopt artificially generated resources is supposed to remain.

Pre-service teachers' needs regarding digital competencies differ based on their subjects and elective courses taken.

Hence, thoughtful strategies and versatile offerings (of courses, activities, and resources) for developing digital skills are needed. The focus group participants provided good practice examples for this, which have interesting features in common:

- All call for active, student-centered learning [22,25] in the context of real-world problems, such as recognizing fake news, editing images, or managing class participation via Excel sheets [42].

- Suggested course scenarios often build upon pre-service teachers' social collaboration, either in teams or in interactive scenarios with the whole class. This corroborates with Ryan and Deci's Self-Determination Theory [15] dimensions of competence and relatedness as basic human needs and hence can provide a powerful motivating element in learning. The social, collaborative component also can be seen as an incentive to build significant learning communities [49] on the theme of a (subset of) digital and social competencies.
- Pre-service teachers wish that teacher educators had a high level of digital competencies that they could pass on to them, an issue also addressed by Masoumi and Noroozi [42]. However, pre-service teachers seem to recognize that teacher educators might not manage to keep up to date with every new tool or device. Thus, pre-service teachers tend to appreciate highly interactive scenarios that include 'teacher-students' who are expected to invest time in mastering selected new tools and passing on their skills and knowledge to students as well as teacher educators who act as facilitators [20] or moderators in interactive sessions and aim to have the "big picture" exposed and reflected in the course.

Surprises were encountered on the way.

We thank one of the reviewers for inviting us to write about unexpected issues. Foremost, pre-service teachers' top motivation and collaboration in the focus group session made the experience of the study highly rewarding and, in turn, motivated us to engage further in the process and research of promoting digital competencies. Pre-service teachers expressed their gratitude for the researchers' listening to their experiences and needs and appreciated being included in the research about digitalization.

Also, pre-service teachers' arguments and experiences made us more fully aware of the complexity immanent in the task of equipping all pre-service teachers with professional digital competencies. Last but not least, we did not expect the high level of empathic understanding that pre-service teachers expressed regarding some teacher educators lacking digital skills. Exploring collaborative, student-centered course formats [22,24] took precedence over criticism and occasional complaints.

Concordant with the results from Wilson et al. [36], the acquired insights urgently need to be acted upon pedagogically, technically, content-wise, and strategically.

4.2. Limitations and Perspectives

A central limitation of this work is that all research, from the underlying online survey to the focus groups, elaborated on in this paper has been conducted in one large central European university only. In an attempt to compensate for this limitation, the authors have related their approach and its outcome to international work.

Another limitation is the fact that it only provides a 'snapshot' of a convenience sample of pre-service teachers' perceptions of their digital competencies in the context of their teacher education program, as revealed in two focus group meetings. The latter were conducted by a team of researchers all having their origins in Central Europe, sharing a humanistic and social constructivist mindset with a solid background in computing. Despite their openness, the cultural and scientific context is likely to impose unwanted bias.

4.3. Contribution and Impact on Theory/Research and Practice

Despite the limitations, we gained precious insights into how to better meet pre-service teachers' needs. Based on the mixed-methods research, including the university-wide survey and focusing on the follow-up focus groups, we derived the following answers to our research questions:

RQ1: Which associations/reactions/suggestions do pre-service teachers with a deep interest in promoting digital skills have when presented with selected results of a university-wide survey on pre-service teachers' digital skills in the context of the teacher education curriculum?

Generally, there is a high concordance between the answers of the focus group participants and those of the survey. The pre-service teachers fully subscribed to the result

that many pre-service teachers do not feel sufficiently prepared by their study program for teaching digital skills. Surprisingly, this also applies to pre-service teachers who studied computing as one of their teaching subjects. As described in Section 3, pre-service teachers strongly emphasized the importance of digital skills for their future profession and stated that they wished for more integration into their training, while still being willing to contribute their part through active, collaborative, and self-organized learning. This would be optimally achieved by a thoughtful, well-engineered interface between the curriculum and self-regulated learning. This finding corroborates the Self-Determination Theory [15], as pre-service teachers expressed that they longed for professional competence through student-centered, active courses, relatedness via collaboration and facilitators, and autonomy via their self-regulated learning as a complement to student-centered courses.

Pre-service teachers argued that if they had more guidance, they would have more motivation, a higher level of understanding, and a greater knowledge exchange, resulting in more confidence in their digital competencies as well as their approaches to teaching them to their students. Intriguingly, these findings gracefully corroborate Vygotsky's concept of the ZPD (Zone of Proximal Development) as the pre-service teachers felt that some guidance by a knowledgeable other would allow them to become more digitally competent than if entirely left on their own [14,48]. Pre-service teachers' quest for guidance shows a situation in which a significant, skilled other person is longed for to accompany them. In this situation, Vygotsky's concept of the ZPD touches on humanistic pedagogy with the notion of a facilitator providing a psychologically nurturing climate as fertile ground for the self-determined actualization of a person [21].

Intriguingly, our results found strong resonance with those discovered in Masoumi and Naroozi's [42] systematic literature review of developing digital competencies for early-career teachers. Therefore, it increases the validity of their work as well as ours. Pre-service teachers described the preferred way of acquiring digital competencies as collaborative, reflective, active, individually designable, building on their pre-knowledge, and practically relevant to their future profession. These characteristics fully resonate with the factors Masoumi and Naroozi [42] identified as contributing to early-career teachers' digital competence development, including technical and pedagogical support, institutional culture, and the availability and accessibility of resources. The high correspondence of our pre-service teachers' perceptions with the international literature encouraged us to reach out and invite interested researchers from other universities to replicate our study for their institutions. The authors would be open to connecting and sharing materials that support research in this field and curriculum development.

In short, the focus group, on the one hand, deepened several survey findings and validated and explained the survey's results and, on the other hand, emphasized the need for a practically relevant, collaborative, personalized, and empowering integration of digital competencies into teacher training.

RQ2: Which insights follow from the focus groups participants' perspectives and which concrete measures can be derived?

While concrete responses to RQ2 and their impact were already discussed in Section 4.1, let us derive further essential implications.

Regarding learning designs and innovative course formats, pre-service teachers wished for a learning design that would aid them in mastering digital competencies while still having a certain degree of freedom and choice. The latter is important to prevent redundancies between courses devoted to the individual subject didactics, and to accommodate for the diverse levels of digital competencies that pre-service teachers have [7,8]. When brainstorming about suitable course designs, the pre-service teachers proposed workshop-like formats. They wished for suitable and comprehensible tutorials in the form of lectures and videos, which should provide them with a range of didactically and legally approved tools, materials, and resources.

Leveraging participatory design and Design-Based Research was requested. From the wishes mentioned above, we conjecture that the integration of digital competencies into

the curricula of teacher education should be designed in concordance with the pre-service teachers and with a close connection to the profession's reality, calling for employing methods such as participatory design [50–52] or Design-Based Research [30]. Moreover, a strong focus should be on collaboration, creativity, and usability [22]. A promising way to derive concrete measures is to examine the good practices, mentioned in the focus groups and the survey, and to critically evaluate which features or patterns would form the basis of any "digital upgrade" course(s) for helping pre-service teachers become digitally competent and supporting them in passing on digital competencies to their students [36].

Establishing effective communication channels.

Our investigation revealed opportunities already in place but not sufficiently well communicated or visible. For example, some pre-service teachers had complained that they were only acquainted with the "consumer side" of platforms such as Moodle, whereby the University of Vienna provides a "playground" for setting up courses in Moodle. There is a need for improved communication about resources that can be used to improve one's digital skills.

In sum, the mixed-method approach we applied proved fruitful. It allowed us to thoroughly explore various aspects of pre-service teachers' digital competencies on a university-wide scale through the survey, and then further enhance our understanding by the focus groups. These focus groups significantly enriched the results of the survey [43]. Both methods proved fruitful in contributing to forming an evidence-based university-wide strategy and concrete first steps toward educating more digitally competent teachers. Finally, the mix of an online setting for the survey and a face-to-face arrangement for the focus group meetings helped to combine the advantages of each of the settings and to mitigate their constraints.

4.4. Further Work

Due to the inherent complexity of orchestrating an effective development of pre-service teachers' digital competencies—a fast-flying target—multiple paths of further work are needed, some of which are mentioned below. To complement pre-service teachers' perspectives on shaping digital competencies, further focus groups should be held with university staff and executives. Moreover, interviews and/or focus groups with lecturers, whose courses qualify as pilots for good practices, would form a good starting point for innovative practice that needs to be communicated, adopted, and made publicly available. In addition, good-practice examples of lessons that promote digital competencies to students would be much appreciated. For teacher educators, coaching workshops, combined with systematically leveraging and reflecting upon AI technology for supporting the self-regulated shaping of digital competencies and generating learning materials for pre-service teachers, should be designed, tested, and researched. Furthermore, research on the social and digital transformation in education in the form of case studies is needed to illustrate real-world challenges and solutions. Finally, the authors aim to encourage further research demonstrating the implementation of digital humanism principles [53] in educating teachers and students to engage in cyberspace and co-create it.

5. Conclusions

Internationally, academic teacher education is challenged to close the gap between teaching subject-specific information and supporting pre-service teachers in acquiring the digital and other future competencies they need in the era of rapidly progressing digital transformation [19,42].

This paper contributes to meeting this challenge by reviewing the related literature and connecting it to the findings from two focus groups with pre-service teachers. The focus groups provided valuable additional insight into the university-wide survey on pre-service teachers' views regarding integrating digital competencies into teacher education [8]. The overall sequential explanatory mixed-method approach proved to be beneficial in several respects. First, the survey results were made more tangible through

the focus groups in which pre-service teachers shared their explanations in a constructive atmosphere that encouraged an open, multi-perspective discourse. This allowed us to gain a deeper understanding of the perceived challenges and to collect ideas on any means that would support pre-service teachers in acquiring the digital competencies they need in their profession. Second, synergies and discrepancies between the current study program and pre-service teachers' needs were discovered. The focus groups uncovered that while pre-service teachers wish for increased integration of digital competencies in their studies, they are prepared to contribute their self-organized part. Examples are exploring and presenting new tools and applications when given collaborative space in highly student-centered course formats, in which pre-service teachers actively use and reflect upon digital technologies [24]. Furthermore, the focus groups clarified that while acquiring basic digital skills in a self-organized way seems indispensable, it does not suffice for mastering distinguished digital competencies at the demanded professional level [36].

Moreover, the pre-service teachers' arguments left no doubt that equipping all pre-service teachers with a set of basic digital competencies, alongside strategic and curricular alignment, is needed. This implies the critical need for collaboration between several educational stakeholders including IT services and legal authorities.

Learning how to pass on digital skills to students at the secondary school level was pivotal, as already found by Røkenes and Krumsvik [32]. This included becoming equipped with highly usable and effective tools, materials, and resources. These results indicate that measures supporting all pre-service teachers to become digitally professional must be taken and strategies must be developed and implemented. Therefore, literature reviews, meta-analyses, and surveys are excellent in sketching the "big picture" [32,35,42]. In addition, focus groups with pre-service teachers have proved helpful in providing essential perspectives to empathically enter the "reality" at a particular institution and highlight the actual needs encountered along with traceable and creative ideas for improving the situation.

Schools are the place where our future society is shaped. Therefore, it is vital to equip pre-service teachers with the necessary digital competencies based on the principles of digital humanism [53] where the human being is at the center. Including pre-service teachers in this endeavor—from the researchers' perspective—is mandatory for the success of the social and digital transformation in education, as is ongoing research to stay tuned and co-construct new developments in a human-centered way.

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