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Pre-Service Teachers' Digital Competence: A Call for Action

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Abstract: In our digital era, pre-service teachers need profound professional digital competences to be able to effectively foster their learners' digital skills. Studies pointing to a lack of integration of digital competences at secondary schools demonstrate the need for research and action to foster professional digital skills in teacher education. Using a mixed methods approach and based on the DigCompEdu framework, this paper presents the results of a survey comprising 75 questions about students' capability to teach digital skills, which was answered by 322 advanced pre-service teachers of a large mid-European university. The results of the performed statistical tests and the conducted thematic analysis show that half of the pre-service teachers do not feel sufficiently prepared by their study program to foster digital competence. Students who do not study a STEM subject and students with teaching practice felt significantly less prepared to teach digital skills compared to students who study at least one STEM subject and students without teaching practice, respectively. We conclude that universities should develop and thoughtfully implement a holistic concept to integrate digital skills in the teacher education curriculum to adequately prepare future teachers for the digital era.

Keywords: digital skills; teacher education; future skills; secondary education; STEM subjects; practice shock

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1. Introduction

There is little dispute amongst educators that the 21st century is shaped and characterized by digitalization. Society's rapid adoption of technology has impacted both the workplace and peoples' lives. As a result of this impact, there is now an increasing importance being placed on the individual to possess the necessary information and communication technology (ICT) skills and digital competences[1] to participate in and responsibly contribute to modern society. As a consequence, educational facilities, who are tasked with preparing students for their future lives as responsible members of society, should teach prospective students these skills and competences. In this matter, teachers become the key element of imparting digital skills and are therefore required not only to possess these kinds of skills but also to have the necessary technological pedagogical knowledge to teach them. Yet, the integration of digital competences in educational practice seems to be challenging and insufficient at many institutions of education, revealing the need for ongoing research regarding the incorporation of digital skills in teacher education.

This study aims to reveal the intricacies of integrating digital competences into the teacher education degree program of the University of Vienna by analyzing advanced pre-service teachers' opinions on their own digital skills and their view of the study program using a university-wide survey with regard to their studied teaching subjects and teaching practice. Potential for improvement as well as barriers are identified and possible measures for further action are derived.

2. Background and Related Work

2.1. Theoretical Framework

Multiple terms have been used in the literature to describe an individual's ability to work with digital technologies, such as ICT literacy (Utakrit & Saelee, 2017), digital literacy (Gorodova et al., 2021), ICT competency (Zhang et al., 2023), digital competency (Lameras & Moumoutzis, 2021), ICT competence (Rubach & Lazarides, 2021), digital competence (Al Shabibi & Al Shabibi, 2021; Brevik et al., 2019; Lucas et al., 2021; Røkenes & Krumsvik, 2016; Urem et al., 2018), ICT skills (Bass, 2007; Salleh et al., 2021), and digital skills (Yooyativong, 2018). As stated by Zhang et al. (2023), a common thread in the literature on digital skills of teachers is that their digital competence should go beyond the mere use of digital technologies and towards the pedagogical usage of ICT—how educators teach is sometimes even more important than what they teach. This finding is also emphasized in the technological pedagogical content knowledge (TPACK) framework (Mishra & Koehler, 2006), which integrates technology, content, pedagogical knowledge, as well as their combinations in a commonly used theoretical model for teacher education.

The European Union has been developing the *DigComp* framework since 2013 (Vuorikari et al., 2022), which models the knowledge, skills, and attitudes required for European citizens to overcome the challenges of the modern digital era. The current version 2.2 defines the five key competence areas "Information and data literacy; Communication and collaboration; Digital content creation; Safety; and Problem solving" (Vuorikari et al., 2022, p. 3). To address the distinctive requirements for educators, the European Union published a separate framework called *DigCompEdu* (Redecker, 2017). The DigCompEdu defines six competence areas, namely 1. professional engagement, 2. digital resources, 3. teaching and learning, 4. assessment, 5. empowering learners, and 6. facilitating learners' digital competence (Redecker, 2017, p. 16). While areas 2–5 focus on a teacher's digital pedagogical competence, area 1 comprises professional skills required for digitally collaborating in a school as an organization. Area 6 explicitly addresses the facilitation of learners' digital competence, which is central to this work.

On a national level, the Austrian Federal Ministry of Education, Science and Research pursued the development of a framework for digital competence at schools called *digi.komp*, which is available for multiple grades (National Competence Center eEducation Austria, 2016) as well as for educators (Brandhofer et al., 2021). This shows the government's awareness of the relevance of digital competences in the educational sector and their efforts.

Based on the reviewed literature, a shortened definition of digital competence was derived to be used in the present research instrument, namely: "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" (Ambros et al., 2022, pp. 1–2). The intention was to highlight the connection between digital competence and modern life while emphasizing that digital competence is more than 'just' being able to use digital technologies.

The underlying theoretical framework for this research and the development of the research instrument were decided to build upon the DigCompEdu framework (Redecker, 2017) due to its international comparability and fine-grained skill definitions, which were reflected in the items of the survey. Considering students' intrinsic motivation and a university's general reliance on self-study, the self-determination theory (Ryan & Deci, 2000) complemented the theoretical framework, which built the basis for other research on teachers' digital competence (Chiu et al., 2024).

2.2. Digital Skills in the 21st Century

Digital skills should be considered in the context of a larger set of skills required in the modern world called *21st century skills*, sometimes also referred to as non-cognitive, soft, or transversal skills or competences (Global Partnership for Education, 2020). The Global Partnership for Education defined the term 21st century skills as "abilities and attributes that can be taught or learned in order to enhance ways of thinking, learning, working and living in the world" (Global Partnership for Education, 2020, p. V), including skills such as creativity, critical thinking, collaboration, and ICT literacy. Thus, the Global Partnership for Education recognizes ICT competence as an integral part of 21st century skills. This aligns with the framework for 21st century learning by Trilling and Fadel (2012), who defined *digital literacy skills* as one of the three skill categories relevant in the 21st century. The tight interweaving of digital competences and 21st century skills has led to the introduction of the term *21st century digital skills* in recent literature (Rubach & Lazarides, 2021; van Laar et al., 2018; Xu et al., 2019).

The question arises how these skills can be taught and acquired in an educational setting. Facilitative conditions for non-academic learning outcomes were found to be self-directed learning (van Laar et al., 2019), student-centered learning (Arsad et al., 2011; Dolezal et al., 2021; Rotherham & Willingham, 2009), self-regulated learning strategies (Anthonysamy et al., 2020), and non-threatening constructivist environments (Sang et al., 2010). Moreover, teaching 21st century skills should go hand in hand with the acquisition of content-related knowledge and skills (Rotherham & Willingham, 2009; Silva, 2009; Valtonen et al., 2021; Voogt et al., 2013) and should be integrated as cross-curricular competences (Voogt & Roblin, 2012), which builds the foundation for the efforts of this research. For teachers to be able to foster students' 21st century and digital skills, it is crucial to include sufficient respective learning opportunities within teacher education programs to enable them to develop these kinds of skills themselves before implementing 21st century digital skills in the classroom (Valtonen et al., 2021; Voogt & Roblin, 2012). Røkenes and Krumsvik (2014) performed a systematic literature review and analyzed a total of 42 studies. They identified eight approaches to promote student teachers' digital competence, namely "collaboration, metacognition, blending, modeling, authentic learning, student-active learning, assessment, and bridging theory/practice gap" (Røkenes & Krumsvik, 2014, p. 250). This again indicates that digital competence is tightly interwoven with other transversal skills, such as reflective thinking and problem solving. They conclude that access to technology is not enough to ensure a pedagogical use of ICT and identified a research gap in the use of ICT in secondary and teacher education, which this paper aims to fill.

2.3. Integration of Digital Skills in Educational Practice

While it is widely acknowledged that digital skills should be included in school curricula and teacher training, the practical implementation in educational practice still seems to be in the early stages of development. Kay (2006) reviewed the literature on the integration of technology in teacher education, including 68 journal articles. He argued that teacher education programs do not sufficiently prepare pre-service teachers for the effective use of technology in the classroom and that there is no common picture of how this should be done. Furthermore, he found that while many of the reviewed articles developed elaborate strategies for the integration of technology in pre-service programs, only a handful of them were systematically conducted and evaluated.

Valcke et al. (2007) held 185 interviews with school leaders, ICT coordinators, and administrators responsible for staff development from a total of 94 different Belgian schools. Given that nearly all of the investigated ICT skills were rated as not developed, at beginners' or basic mastery level by the interview partners, they concluded that the implementation of ICT skills in educational practice is rather fragmented and missing a broader vision regarding the use of ICT for subject didactics.

Gudmundsdottir et al. (2014) surveyed newly qualified teachers at 581 Norwegian schools, amounting to a total of 375 responses. Their results showed that while new teachers tended to have a positive attitude towards the use of ICT in the classroom, they saw only a little correspondence between ICT competences taught in teacher education programs and those expected in professional practice.

Maderick et al. (2016) surveyed 174 pre-service teachers at a large southwestern university in the United States. They compared students' self-assessment of digital competences to an objective assessment using multiple-choice questions and found that pre-service teachers significantly overestimated their digital skills, scoring rather poorly on the objective scale. Maderick et al. highlighted the need for an accurate means of assessment to be able to provide students with appropriate learning opportunities within a teacher education program.

Aslan and Zhu (2016) compared the responses of 200 pre-service teachers to those of 105 beginning teachers in a survey regarding the integration of ICT in the classroom in Turkey. While the general perceived ICT competence was rather high in both groups, their average perceived competence regarding the integration of ICT in lessons was only slightly above or even below the neutral response. Interestingly, they found that new in-service teachers reported being less confident regarding the use of ICT in the classroom than pre-service teachers, hypothesizing that pre-service teachers may be more competent regarding this matter. Other studies also found younger teachers more digitally competent (see, e.g., Jiménez-Hernández et al., 2020). Aslan and Zhu emphasized the need for change in teacher education programs to better prepare teachers for the use of ICT in professional practice.

Tondeur et al. (2017) published their findings of a longitudinal study with 16 beginning teachers carried out over four years. They held in-depth interviews and concluded that while beginning teachers generally indicated a positive attitude towards the integration of ICT in the classroom, "only a limited number of exemplary beginning teachers are able to create opportunities for student-centred use of technology" (Tondeur et al., 2017, p. 172). As a possible explanation for this, Tondeur et al. suggested a "reality shock" (Tondeur et al., 2017) resulting from the challenging transition from teacher education to educational practice, naming the workload and school culture as influencing factors. Other literature uses the term "practice shock" (Stokking et al., 2003) to describe this effect.

A report summarizing the results of a survey among 800 public schools, including elementary, middle, and high schools in the 50 states of the United States, revealed an average ratio of 1.1 students per computer (Gray et al., 2021) in 2021, which can be seen as a major increase over twelve years from an average ratio of 5.3 (Gray et al., 2009). However, 53% and 47% of the surveyed schools reported that their teachers were provided no or only to a small extent "professional development on mechanics of how to use a computer or software [and] how to use technology for instructing specific curriculum areas" (Gray et al., 2021, p. 23) respectively. This supports the hypothesis of a lacking integration of technology in teacher education and training.

Masoumi and Noroozi (2023) performed a systematic literature review on the development of early career teachers' digital competence in practice. Based on their analysis of the 25 journal articles that met the inclusion criteria from the year 2000 and onwards, they found several studies reporting that many beginning teachers were not able to create student-centered learning environments using digital technologies. Factors contributing to the development of digital competence were derived, namely institutional culture, the availability of resources, technical and pedagogical support, and beginning teachers' workload, the latter of which negatively affects their adoption of digital technologies in teaching. They highlighted the need for more studies, including the role of educational institutions in the development of digital competence—to which this article contributes.

A survey among seven students and an interview series with five educators of the English as a Foreign Language teacher education program of the University of Vienna revealed several digital competences that were not covered sufficiently in the study program, such as data protection, device security, computational thinking, and problem solving (Jemetz et al., 2023). Identified prerequisites for the successful integration of digital skills in teaching, which were often not met, including tool support, training, literature, and support in developing educators' digital skills as well as teaching them. They called for further studies covering additional teaching subjects; this paper gives a comprehensive overview of all teaching subjects offered at the University of Vienna.

Several studies already shed light on teachers' digital competence in relation to their taught subjects. Based on the DigCompEdu framework, Vieira et al. (2023) surveyed the digital proficiency of 20,935 Portuguese in-service teachers. Their results showed that biology and geology teachers reported a significantly higher digital proficiency than teachers of the subjects physics and chemistry, mathematics and natural sciences, and mathematics. Jang and Tsai (2012) developed a questionnaire to investigate primary school teachers' TPACK in Taiwan. Their analysis of the 614 responses revealed that science teachers reported significantly higher TPACK scores than mathematics teachers. Endberg and Lorenz (2017) analyzed the results of a survey based on the TPACK model among 1218 German secondary school teachers. They found that STEM teachers used computers more frequently in class and felt more capable of guiding other teachers in integrating content, technology, and pedagogy compared to non-STEM teachers. Using the DigCompEdu framework and a designed self-assessment instrument, Ghomi and Redecker (2019) surveyed the digital competence of 335 German primary, secondary, and vocational school teachers. Their results revealed that STEM teachers and computer science teachers reported significantly higher scores compared to non-STEM and non-computer science teachers respectively. The literature therefore suggests that STEM teachers tend to be more digitally competent and have a higher affinity for computers; however, no study has yet addressed this matter in the case of pre-service teachers, especially concerning the aforementioned practice shock. This paper aims to close this research gap.

A survey among 15 graduates and in-service teachers of all four Austrian teacher education associations of academic institutions revealed that seven of the respondents did not feel qualified to integrate digital competences into their teaching (Prenner, 2020). Ten respondents stated that there were no additional possibilities to take elective courses regarding digital competences. Based on these findings, this paper presents the results of a large-scale university-wide survey at the University of Vienna regarding the integration of digital competences in teacher education with respect to pre-service teachers' studied teaching subjects and teaching practice. The first findings and a descriptive summary of selected items have already been presented to the engineering education community (Ambros et al., 2022); this contribution represents the first comprehensive and holistic evaluation of this study.

2.4. Teacher Education Program in the Austrian North-Eastern Association of Academic Institutions

The teacher education program for the secondary level (University of Vienna, 2025) comprises a bachelor's degree program of 240 European Credit Transfer System (ECTS) credits (about 8 semesters) and a master's degree program of 120 ECTS credits (about 4 semesters) in the North-Eastern association of academic institutions. Teacher education students have to choose two teaching subjects in their bachelor's program or one teaching subject plus inclusive pedagogy but are free to enroll in more. Students are required to attend courses with a total of 100 ECTS in each teaching subject to qualify for the respective subject. The general educational basics constitute the remaining 40 ECTS and are therefore mandatory for all students. Students also complete an internship within the scope of their study program. Typically, students start to work as teachers after graduating from their bachelor's degree program and do their master's studies along the way. The master's degree program is structured similarly and involves 35 ECTS for each teaching subject, 20 ECTS for general educational basics, and 30 ECTS for the graduation phase.

Within the scope of the Teaching Digital Thinking (TDT) project, which is funded by the Austrian Federal Ministry of Education, the aim of the research is to constructively influence the effects of digital transformation on teaching and learning with a focus on improving the mediation of digital skills in the teacher education program. While this study is specific to the North-Eastern association of academic institutions (including the University of Vienna) offering teacher education programs in Austria, related research allows to assume that the findings and their implications would be relevant far more widely.

2.5. Research Questions

This work aimed to identify gaps, deepen the investigation of the status quo of the integration of digital skills in the teacher education program of the University of Vienna and associated university colleges, and derive recommendations for further actions. To address this, teacher education students' opinions on these aspects were investigated. Since students need to have already experienced the teacher education program to a certain degree to give a reliable estimate of it, this work focused on *advanced pre-service teachers*, defined as:

- all students of the teacher education bachelor's degree program with more than 180 completed ECTS (i.e., completed about at least 75% of their studies)
- all students of the teacher education master's degree program

Based on this, the study addresses the following research questions:

(RQ1) To what extent do advanced pre-service teachers feel prepared through their teacher education program to foster their future students' basic digital skills?

(RQ2) What opportunities for improvement regarding the integration of digital skills in teacher education can be derived?

While the paper deals with the aforementioned research questions and is structured accordingly, the research additionally aimed to investigate several hypotheses. First, the connection between studied teaching subjects and students' reported digital skills should be researched. In detail, it should be found out whether teacher education students who do not study at least one STEM subject were at higher risk of missing out on essential digital skills than students who study at least one STEM subject, although both groups of teachers are expected to integrate digital skills in their teaching. While it is assumed that many students miss certain digital skills in their studies, such as the pedagogical aspects of fostering digital skills, it may be reasonable that students with a stronger background in STEM feel more digitally competent, which is also supported by the literature (Das & Bhattacharyya, 2023; Endberg & Lorenz, 2017; Ghomi & Redecker, 2019). Therefore, this work hypothesizes:

Hypothesis 1. *Teacher education students who study at least one STEM teaching subject report a higher level of digital skills than students who do not study at least one STEM teaching subject.*

To investigate this matter further, the research also aimed to analyze the special case of teacher education students of computer science (CS). It seems natural for CS students to feel more digitally competent than non-CS students due to their courses on CS topics and is also supported by the literature (Ghomi & Redecker, 2019). Hence, it is hypothesized:

Hypothesis 2. *Teacher education students of computer science report a higher level of digital skills than students who do not study the teaching subject computer science.*

The underlying intention of both H1 and H2 is to find out whether students of STEM subjects or CS students may act as catalysts for spreading digital competence among their peers.

Finally, students' teaching experience and its relation to their reported digital skills should be examined. While at first glance, it may seem intuitive for pre-service teachers to become more confident in their digital skills the more teaching experience they have acquired (see also Jang and Tsai, 2012), the opposite effect was observed in the literature for beginning teachers (Stokking et al., 2003; Tondeur et al., 2017). Especially beginning teachers may feel overwhelmed by the transition to practice, thus experiencing standing in the classroom and being confronted by the challenges of a teacher's life for the first time. This work hypothesizes:

Hypothesis 3. *Teacher education students who have already acquired teaching practice beyond the guided practice as part of their study feel less confident in their digital skills than students who have not yet independently acquired teaching practice.*

3. Materials and Methods

3.1. Research Design and Data Collection

Due to the multifacetedness of the research questions, this study combined quantitative and qualitative methods; hence, a mixed methods research approach has been employed. As the research was looking for an explanation and interpretation for this social research at the same time, the underlying mixed methods research paradigm can be seen as a realist approach (Hall, 2013). While the quantitative methods give a benchmark and help find significant differences and connections, the parallel qualitative approach offers the possibility to interpret the observed effects and provides valuable insight into students' perspectives as well as potentials for improvement, from which recommendations for further action and research can be derived.

To gather quantitative as well as qualitative data, a survey was constructed comprising both closed and open questions. The questionnaire consisted of four sections: 1. general information and demographics, 2. digital competences in the teacher education program, 3. opportunities for improvement in the teacher education program, and 4. concluding questions. In total, respondents were presented with 75 questions, 12 of which were open-ended. Parts of the questionnaire were based on a prior study carried out by the University of Graz (Bernsteiner et al., 2023), which is also part of the Teaching Digital Thinking project and primarily built on the validated items of Vogelsang et al. (2019).

As sketched in a preceding conference paper (Ambros et al., 2022), data collection was performed in five steps. First, a prototype of the questionnaire was prepared in Microsoft Forms (Microsoft, 2025) and validated in a pilot study with five test participants. In a second step, their feedback was collected and considered in the final version of the questionnaire, which was carefully prepared in a university-hosted LimeSurvey environment (LimeSurvey, 2025). Third, various entities of the university were consulted to guarantee conformity with the university's guidelines for data protection and privacy, including Quality Assurance, Teaching Affairs and Student Services, the Center for Teaching and Learning, the works committee, and the Rectorate, which gave the final permission to conduct the survey.

Fourth, all students of the master's degree program as well as all students of the bachelor's degree program with more than 180 ECTS were added to the recipient list of the survey, which comprised 4054 records. Access tokens were generated for all recipients to allow them to save and continue their answers to the survey and to avoid duplicate entries. Finally, the survey was sent out on 24 February 2022; two reminders were sent on 9 March and 18 March respectively. Thus, the survey was online and open for 27 days. Participants were informed about the specific purpose of the survey, the anonymity, and the voluntariness before they were asked to provide their consent by answering the survey.

3.2. Sample Description

Table 1 summarizes the characteristics of the 322 complete responses; the additional 319 partial responses were excluded from this analysis. Thus, considering the survey was sent to 4054 students, the overall response rate was 7.9%. On average, it took the respondents 17 min and 43 s to answer the survey.

The two most present teaching subjects in absolute numbers were two non-STEM subjects, namely German as well as history and political education, making up nearly a third of all answers. To address H1, teaching subjects were categorized in STEM and non-STEM subjects. About half of the respondents chose at least one STEM subject as one of their teaching subjects. The majority of the respondents were students of the master's degree program. 55% of the respondents had no teaching experience or only completed the mandatory internship and were categorized as having 'no professional practice' to investigate H3.

Table 1. Sample Description of Respondents (n = 322).

Characteristic	n (%)
Teaching subject according to University of Vienna (2025)	703 (100%)
Biology and Environmental Education [1]	52 (7.4%)
Bosnian/Croatian/Serbian	2 (0.3%)
Catholic Religion	8 (1.1%)
Chemistry [1]	11 (1.6%)
Computer Science [1]	17 (2.4%)
Descriptive Geometry [1]	2 (0.3%)
English	69 (9.8%)
Ethics	6 (0.9%)
French	32 (4.6%)
Geography and Economic Education [1]	65 (9.2%)
German	116 (16.5%)
Greek	3 (0.4%)
History and Political Education	99 (14.1%)
Home Economics and Nutrition	8 (1.1%)
Hungarian	2 (0.3%)
Inclusive Education	18 (2.6%)
Italian	12 (1.7%)
Latin	15 (2.1%)
Mathematics [1]	54 (7.7%)
Other [2]	12 (1.7%)
Physics [1]	17 (2.4%)
Protestant Religion	2 (0.3%)
Psychology and Philosophy	39 (5.5%)
Russian	5 (0.7%)
Slovakian	1 (0.1%)
Spanish	18 (2.6%)
Sports and Physical Education	18 (2.6%)

Table 1. *Cont.*

Characteristic		n (%)
STEM subject		322 (100%)
	1+ STEM subjects	163 (50.6%)
	No STEM subject	159 (49.4%)
Degree program		331 (100%)
	Bachelor's degree program	114 (34.4%)
	Master's degree program	209 (63.1%)
	Graduate of master's degree program	3 (0.9%)
	Other [3]	5 (1.5%)
Teaching experience		322 (100%)
	No teaching experience [4]	6 (1.9%)
	Internship completed [4]	171 (53.1%)
	Worked as a teacher	9 (2.8%)
	Working as teacher, first year	59 (18.3%)
	Working as teacher, second year	33 (10.3%)
	Working as teacher, third+ year	19 (5.9%)
	Other [5]	25 (7.8%)
Professional practice		322 (100%)
	No professional practice	177 (55.0%)
	Professional practice	145 (45.0%)

Note. Teacher education students have to decide for two teaching subjects or more. [1] Marked subject was categorized as STEM subject. [2] Category 'other subject' includes music, arts, handcrafts, and Islamic religion. [3] Category 'other degree program' includes graduates of bachelor's degree program, expired diploma degree programs, and interdisciplinary degree programs. [4] Marked answer was categorized as 'no professional practice'. [5] Category 'other teaching experience' includes summer school, tertiary teaching, work as teaching assistant, tutoring, on paternity leave, and international teaching.

Overall, the sample was rather balanced, exhibiting a fair distribution of STEM- and non-STEM students as well as learners with and without notable teaching practice.

3.3. Quantitative Data Analysis and Thematic Analysis

As the underlying quantitative data used ordinal scales, Mann-Whitney U tests and Kruskal-Wallis tests were used to evaluate the significance of observed differences. The quantitative data analysis was carried out in R 4.4.0.

To gain better insight into the qualitative data and estimate the importance of certain topics, a thematic analysis (Vaismoradi et al., 2013) of three of the twelve open-ended questions was carried out for this article. The three questions were selected due to their direct contribution to the research questions—the acquisition of digital skills and suggestions for improvement—and to keep the paper concise. The thematic analysis was carried out in four steps. First, one researcher split the answers into meaning units, which were defined as an independent coherent word, phrase, sentence, or sequence of sentences focusing on one aspect. Second, the same researcher inductively derived a set of codes based on the meaning units. Third, two to three researchers rated the meaning units using the provided set of codes but were free to define additional codes and suggest changes to the provided set of codes. Finally, the researchers discussed the differences, sharpened the code definitions, agreed upon a final coding of the meaning units in two separate sessions, and identified emerging themes the codes were assigned to. The analysis was carried out in Microsoft Excel.

3.4. Validity and Reliability

Several measures have been taken to ensure the validity and reliability of the survey. First, large parts of the questionnaire were based on competence descriptions of recognized digital competence frameworks (Becker et al., 2020; Brandhofer et al., 2021; Redecker, 2017) and validated questionnaires (Vogelsang et al., 2019). Second, to validate new questions and re-validate the existing ones in this context, the aforementioned pilot study with five test participants of the target audience was performed and the gathered feedback was incorporated. Third, feedback was collected from the university's Center for Teaching and Learning, which is experienced in conducting large-scale surveys among students.

To (re-)confirm the reliability and internal consistency of the questionnaire, Cronbach's alpha (Cronbach, 1951) was calculated for all four sets of questions, namely the overall assessment, taught digital skills in the teacher education program, students' self-assessed capabilities, and suggestions for improvement. The respective values were 0.61, 0.78, 0.95, and 0.88; hence, the sets of questions can be seen as reliable ($\alpha > 0.6$) (Ursachi et al., 2015). The inter-rater reliabilities of the three thematic analyses were evaluated by calculating Conger's kappa (Conger, 1980), an extension of Cohen's kappa (Cohen, 1960) for more than two raters, of the respective first rating sessions. The resulting kappa values were 0.511, 0.666, and 0.590 respectively; the initial agreement strength can therefore be seen as "moderate" to "substantial" (Landis & Koch, 1977). After two iterations in which valuable discussions stemming from the diverse perspectives of the international raters took place, a consensus was reached, converging to perfect scores.

4. Results

4.1. Digital Skills in the Teacher Education Program

Pre-service teachers' *overall assessment of their ability to promote digital competence* is shown in Table 2 alongside their opinion on the integration of digital skills in their teacher education program. Several observations can be made. First, 49% of the respondents disagreed or rather disagreed with feeling well prepared through their studies to foster their future students' digital skills. Teacher education students with at least one STEM teaching subject felt significantly better prepared to foster digital skills than their peers with $p = 0.043$. H1 is supported. Students with professional practice felt significantly worse prepared to foster their learners' digital competence than those without professional practice as indicated by a Mann-Whitney test returning $p = 0.044$, supporting H3.

Second, 73% of the respondents (rather) disagreed with the statement that *digital skills are sufficiently integrated into the courses of their teacher education program*. Two significant differences could be observed regarding their selected study programs: Students studying at least one STEM subject rather tended to agree with this statement ($p = 0.025$), which also applied to students of the teaching subject CS ($p = 0.032$). The results therefore support H1 and H2.

Table 2. Frequencies of Students' Overall Assessment of Digital Skills in Their Studies; Grouped by Professional Practice, Subject Computer Science, and STEM Subject.

	Disagree (0)	Rather Disagree (1)	Rather Agree (2)	Agree (3)	M (±SD)
"Overall, I feel well prepared through my studies to support my students in the acquisition of digital skills."					
Total	72	84	116	47	1.43 (±1.00)
STEM *	32	42	57	32	1.55 (±1.02)
Non-STEM *	40	42	59	15	1.31 (±0.96)
CS	4	1	7	5	1.76 (±1.15)
Non-CS	68	83	109	42	1.41 (±0.99)
Prof. pract. *	37	45	40	21	1.31 (±1.02)
No prof. pract. *	35	39	76	26	1.53 (±0.97)

Table 2. *Cont.*

	Disagree (0)	Rather Disagree (1)	Rather Agree (2)	Agree (3)	M (±SD)
"Digital skills are sufficiently integrated into the courses of my teacher education program."					
Total	123	111	62	24	0.96 (±0.94)
STEM *	54	60	30	19	1.09 (±0.99)
Non-STEM *	69	51	32	5	0.83 (±0.86)
CS *	4	4	6	3	1.47 (±1.07)
Non-CS *	119	107	56	21	0.93 (±0.92)
Prof. pract.	55	46	31	12	1.00 (±0.97)
No prof. pract.	68	65	31	12	0.93 (±0.91)
"Digital skills are covered more in subject didactics than in general educational basics."					
Total	52	36	64	157	2.06 (±1.14)
STEM	20	17	34	85	2.18 (±1.07)
Non-STEM	32	19	30	72	1.93 (±1.20)
CS	1	4	2	10	2.24 (±1.03)
Non-CS	51	32	62	147	2.04 (±1.15)
Prof. pract. *	27	21	29	60	1.89 (±1.17)
No prof. pract. *	25	15	35	97	2.19 (±1.10)
"In my opinion, digital skills should play a bigger role in general educational basics."					
Total	13	18	59	214	2.56 (±0.79)
STEM	6	16	30	102	2.48 (±0.83)
Non-STEM	7	2	29	112	2.64 (±0.74)
CS	1	1	5	10	2.41 (±0.87)
Non-CS	12	17	54	204	2.57 (±0.79)
Prof. pract.	4	11	24	95	2.57 (±0.77)
No prof. pract.	9	7	35	119	2.55 (±0.81)

Note. Question and answer options have been translated from German. * $p < 0.05$.

Third, a majority of pre-service teachers (72%) agreed or rather agreed that the *subject didactics covered more digital skills than the courses of the general educational basics*. Students with professional practice tended to agree less than their peers without professional practice, which was found significant by a Mann-Whitney test returning $p = 0.020$. This indicates a practice shock and thus partially supports H3.

Finally, regarding the wish for *better integration of digital skills in the general educational basics*, the respondents seemed to agree: 90% of the respondents (rather) agreed with the respective statement.

Table 3 depicts pre-service teachers' estimation of the *percentage of digital skills that they have acquired through their studies or on their own*. 72% of the respondents stated to have acquired only 25% or less of their digital skills through their studies. Students with professional practice estimated the digital skills acquired at university highly significantly lower ($p < 0.001$), supporting H3. The overall average of students' estimation is 29%; hence, pre-service teachers tend to see their digital competence rather as an accomplishment of their own. To further investigate this matter, an in-depth analysis of the acquired skills at the university and students' suggestions for improvement was performed.

Table 3. Frequencies of Students' Estimate of Their Acquisition of Digital Skills in Their Studies; Grouped by Professional Practice, Subject Computer Science, and STEM Subject.

"How much of your digital skills have you acquired directly through your studies and how much of them have you acquired on your own?"						
	I acquired 0% of my digital skills as part of my studies, 100% through self-study or prior knowledge. (0)	**I acquired 25% of my digital skills as part of my studies, 75% through self-study or prior knowledge. (25)**	**I acquired 50% of my digital skills as part of my studies, 50% through self-study or prior knowledge. (50)**	**I acquired 75% of my digital skills as part of my studies, 25% through self-study or prior knowledge. (75)**	**I acquired 100% of my digital skills as part of my studies, 0% through self-study or prior knowledge. (100)**	**M (±SD)**
Total	49	184	76	13	0	29.1 (±18.1)
STEM	18	95	45	5	0	30.7 (±17.0)
Non-STEM	31	89	31	8	0	27.5 (±19.1)
CS	2	8	6	1	0	33.8 (±19.6)
Non-CS	47	176	70	12	0	28.9 (±18.0)
Prof. pract. **	30	87	23	5	0	25.5 (±17.8)
No prof. pract. **	19	97	53	8	0	32.1 (±17.9)

Note. Question and answer options have been translated from German. ** $p < 0.01$.

Figure 1 as well as Table 4 summarize teacher education students' reported encountered *digital skills and tools* during their studies. Most respondents stated to have used digital textbooks, written texts using digital media, used digital media to study, and used learning platforms to design learning environments (very) often in the course of their studies. About half of the teacher education students reported having used digital tools to give feedback, enabled collaboration among students using digital media, learned to consider legal aspects regarding digital media, prepared teaching content with digital media, and used smartphones often or very often in their studies. Only about a third of the respondents reportedly used spreadsheet programs, created educational videos, and dealt with ethical issues of digitization often or very often. The least present skills were evaluating experiments using video analysis, modeling processes, and working with augmented reality applications.

H1 is supported in the case of using spreadsheet programs ($p < 0.001$) and modeling processes with computer programs ($p < 0.001$), as students studying at least one STEM subject reported a significantly higher agreement.

Pre-service teachers who chose CS as one of their subjects reported an increase in using spreadsheet programs ($p = 0.047$), working with augmented reality applications ($p = 0.043$), modeling processes with computer programs ($p = 0.003$), considering legal aspects when using digital media ($p < 0.001$), and dealing with ethical issues of digitization ($p < 0.001$). H2 is therefore supported in these aspects.

Students with professional practice reported having prepared teaching content with digital media and used digital textbooks significantly less frequently in their studies, as found by a Mann-Whitney U test returning $p < 0.001$ and $p = 0.002$ respectively, supporting H3.

To deepen the understanding of students' answers, they were provided with the opportunity to comment on the block of Likert-scale questions; the thematic analysis of students' comments can be seen in Table 5. Students' comments revolved around three emerging themes, which were about equally present. The first theme represents comments addressing the *acquisition of digital skills at the university*. The respondents elaborated that the acquired digital competences not only depend on selected teaching subjects but also on individual focus subjects and writing seminar papers on self-chosen topics.

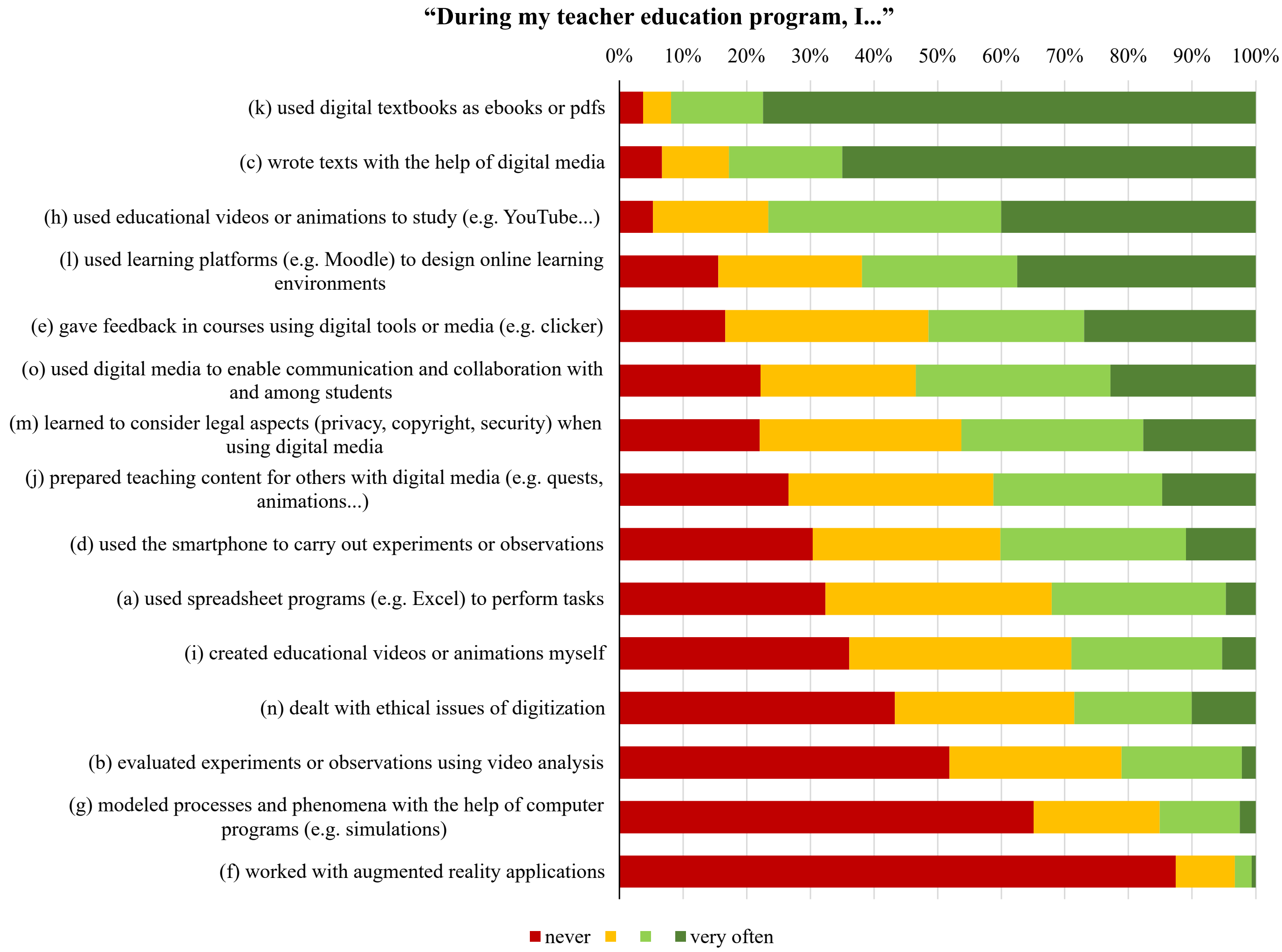

Figure 1. Bar Chart Visualizing Taught Digital Skills in the Teacher Education Program According to Students. *Note.* Question and answer options have been translated from German. Items (a)–(k) are based on Bernsteiner et al. (2023), who built on Vogelsang et al. (2019).

The second identified theme comprises comments implying that *digital skills were acquired outside the university*. A considerable number of students stated to have acquired digital skills in the course of their teaching practice. Another observed opinion was that pre-service teachers claimed to have acquired digital skills rather through self-study than having learned them at the university. A deeper analysis of the comments did not reveal whether students felt positive or negative about this. Some students also highlighted that the COVID-19 pandemic played an important role in this matter.

The third theme deals with the *barriers to the acquisition of digital skills*. Several students criticized the lack of integration of digital competences at the university. Additional comments expressed a desire for concrete examples, concerns about the quality of on-campus teaching, a wish for better technical equipment, a need to use learning platforms from a teacher's point of view, and criticism regarding having to learn facts by heart.

Two remaining comments addressed *remarks* on the questionnaire. Respondents were always offered the option to provide no answer if something was unclear to them.

Students' self-reported *capability to teach different digital skills* is shown in Figure 2 as well as Table 6. About two-thirds of the future teachers felt (rather) confident regarding their ability to use digital media to present, handle information, and continue their digital education. About 50% of the respondents felt (rather) capable of using digital media to prepare lessons, communicate and collaborate, actively involve learners, consider copyright issues, manage the learning process, consider subject-specific matters, coordinate group work, collect data, use fact-checking strategies, use social media for teaching and learning, and promote learners' digital skills. The respondents felt least prepared to process data, evaluate the level of learning using digital tools, deal with aspects of data protection and security, administer class and school, and consider ethics, media education, as well as accessibility in class.

Table 4. Taught Digital Skills in the Teacher Education Program According to Students; Grouped by Professional Practice, Subject Computer Science, and STEM Subject.

"During my teacher education program, I…"							
Statement	**Total**	**STEM**	**Non-STEM**	**CS**	**Non-CS**	**Prof. Practice**	**No Prof. Practice**
n	322	163	159	17	305	145	177
	M (± SD)						
(a) used spreadsheet programs (e.g., Excel) to perform tasks	1.04 (±0.89)	1.34 ** (±0.84)	0.74 ** (±0.83)	1.47 * (±0.87)	1.02 * (±0.88)	1.03 (±0.83)	1.05 (±0.93)
(b) evaluated experiments or observations using video analysis	0.71 (±0.85)	0.75 (±0.86)	0.68 (±0.84)	0.53 (±0.80)	0.72 (±0.85)	0.70 (±0.83)	0.72 (±0.86)
(c) wrote texts with the help of digital media	2.41 (±0.93)	2.44 (±0.91)	2.38 (±0.94)	2.47 (±0.80)	2.41 (±0.93)	2.29 (±1.03)	2.51 (±0.82)
(d) used the smartphone to carry out experiments or observations	1.21 (±1.00)	1.19 (±0.97)	1.23 (±1.03)	0.94 (±0.83)	1.22 (±1.01)	1.15 (±0.96)	1.25 (±1.03)
(e) gave feedback in courses using digital tools or media (e.g., clicker)	1.62 (±1.05)	1.65 (±1.05)	1.59 (±1.06)	1.47 (±0.94)	1.63 (±1.06)	1.54 (±1.04)	1.68 (±1.06)
(f) worked with augmented reality applications	0.17 (±0.48)	0.19 (±0.47)	0.14 (±0.49)	0.29 * (±0.47)	0.16 * (±0.48)	0.15 (±0.51)	0.18 (±0.46)
(g) modeled processes and phenomena with the help of computer programs (e.g., simulations)	0.53 (±0.81)	0.85 ** (±0.90)	0.19 ** (±0.52)	1.00 ** (±0.79)	0.50 ** (±0.80)	0.58 (±0.83)	0.48 (±0.79)
(h) used educational videos or animations to study (e.g., YouTube…)	2.11 (±0.89)	2.15 (±0.86)	2.08 (±0.91)	2.13 (±0.81)	2.11 (±0.89)	2.08 (±0.91)	2.14 (±0.86)
(i) created educational videos or animations myself	0.98 (±0.90)	0.98 (±0.91)	0.99 (±0.89)	1.18 (±0.73)	0.97 (±0.91)	0.89 (±0.89)	1.06 (±0.91)
(j) prepared teaching content for others with digital media (e.g., quests, animations…)	1.29 (±1.02)	1.29 (±1.01)	1.30 (±1.03)	1.35 (±1.06)	1.29 (±1.02)	1.08 ** (±1.00)	1.47 ** (±1.00)
(k) used digital textbooks as ebooks or pdfs	2.66 (±0.74)	2.68 (±0.70)	2.64 (±0.77)	2.75 (±0.77)	2.65 (±0.73)	2.49 ** (±0.90)	2.79 ** (±0.53)
(l) used learning platforms (e.g., Moodle) to design online learning environments	1.84 (±1.10)	1.73 (±1.08)	1.95 (±1.10)	2.06 (±0.68)	1.83 (±1.11)	1.84 (±1.12)	1.84 (±1.08)
(m) learned to consider legal aspects (privacy, copyright, security) when using digital media	1.42 (±1.02)	1.46 (±1.01)	1.38 (±1.03)	2.24 ** (±0.75)	1.37 ** (±1.02)	1.50 (±1.02)	1.36 (±1.02)
(n) dealt with ethical issues of digitization	0.95 (±1.01)	0.92 (±0.95)	0.99 (±1.07)	1.94 ** (±0.83)	0.90 ** (±0.99)	0.90 (±1.00)	0.99 (±1.02)
(o) used digital media to enable communication and collaboration with and among students	1.54 (±1.07)	1.48 (±1.07)	1.61 (±1.08)	1.59 (±0.94)	1.54 (±1.08)	1.51 (±1.12)	1.56 (±1.03)

Note. Question, statements, and answer options have been translated from German and used a 4-point semantic differential scale ranging from never (0) to very often (3). Items (a)–(k) are based on Bernsteiner et al. (2023), who built on Vogelsang et al. (2019). * $p < 0.05$. ** $p < 0.01$.

Table 5. Thematic Analysis of Additional Comments on Taught Digital Skills in the Teacher Education Program According to Students.

"Additional comments on the set of questions above:"		
Theme/Code	**Exemplary Statement**	**Frequency**
Acquisition of Digital Competences at University		11
Acquisition dependent on teaching subject of studies	In my opinion, many of the items of the set [are] dependent on subject and "science" (natural sciences vs. languages)	4
Acquisition dependent on individual focus	Dealing with legal aspects and ethical concerns that often was not an integral part of my studies, but was rather a result of my individual prioritization	3
A chosen few digital competences acquired at university	In the courses, it [copyright law] was only featured in "Computer Science and Law" and briefly in one pedagogy course	2
All digital competences acquired at university	Yes, overall, I did all of this	1
Facilitation through lecturers	But I experienced multiple times that a lecturer considered students' interests also in this regard and integrated or excluded aspects, and I find this better than a rigid course.	1
Acquisition of Digital Competences Outside University		13
Acquisition through teaching practice	I acquired all of these things on my own as part of my teaching activity	6
Acquisition through self-study	The usage yes, but mostly in self-study	4
Boost through pandemic	The pandemic made many things necessary in this regard, e.g., digital meetings in study groups on Zoom, collaborate, ... since face-to-face meetings were not allowed	3
Barriers to Acquisition of Digital Competences		11
Hardly any digital competences taught at university	the university taught me absolutely nothing in this field, I find that's a great pity	6
Desire for concrete examples	I would also like to learn simple things, such as designing a worksheet, creating a proper layout, using suitable fonts, scaling in Word documents, etc.	1
Digital competences at expense of on-campus teaching	but as I said before, normal on-campus teaching suffers from this, you learn barely something new, but everyone in the teaching subjects does digital things and possibilities in class in detail	1
Insufficient technical equipment	Due to the technical equipment, some things are not/would not be possible (affordable), it was already a challenge to make it this far in my studies with my laptop and Windows XP, and I still had to borrow a newer one with Windows 10 and a camera for the video conferences	1
Only used from learner's view	I used Moodle only from a learner's view, not as a teacher	1
Too much theory taught at university	At the same time, I had to memorize when Austria achieved what performance in which educational study or what Freud thought of education	1
Feedback and Comments		2
Questionnaire feedback and comments	Some questions were unclear to me, e.g., I don't know what "Clicker" is	2

Note. Question and exemplary answers have been translated from German.

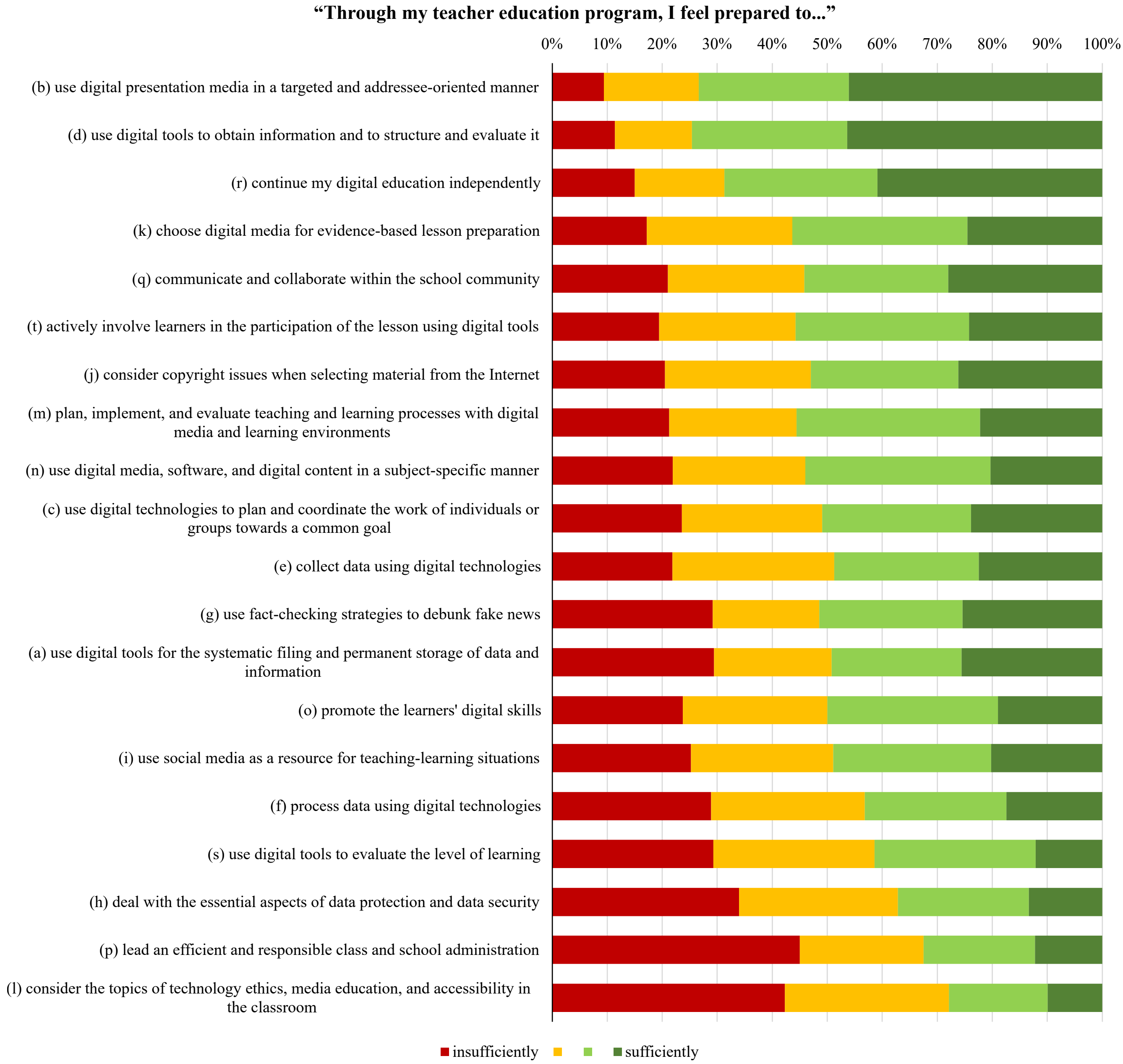

Figure 2. Bar Chart Visualizing Students' Self-Assessed Capability to Teach Digital Skills. *Note.* Question and answer options have been translated from German. Items (a)–(k) are based on the work of Mandl et al. (2022), who built on the DiKoLAN framework (Becker et al., 2020). Items (l)–(r) are derived from the areas of the national digi.kompP framework (Brandhofer et al., 2021). Items (s) and (t) are based on competences of the DigCompEdu framework (Redecker, 2017).

The statistical analysis revealed several significant differences. STEM teacher education students felt better prepared to collect and process data using digital technologies, as found by a Mann-Whitney test that estimated $p = 0.037$ and $p = 0.002$ respectively, supporting H1 for these skills.

Students of the teaching subject CS reported being significantly better prepared in half of the analyzed skills; H2 is therefore accepted for the skills filing and storing data ($p = 0.048$), coordinating work ($p = 0.0340$), processing data ($p = 0.014$), dealing with data protection and security ($p = 0.016$), considering copyright issues ($p = 0.001$), considering technology ethics, media education, and accessibility in the classroom ($p = 0.003$), using digital technologies in a subject-specific manner ($p = 0.015$), promoting learners' digital skills ($p = 0.014$), continuing their digital education ($p = 0.019$), and using digital tools to evaluate learning ($p = 0.008$).

Table 6. Students' Self-Assessed Capability to Teach Digital Skills; Grouped by Professional Practice, Subject Computer Science, and STEM Subject.

"Through my teacher education program, I feel prepared to…"							
Statement	**Total**	**STEM**	**Non-STEM**	**CS**	**Non-CS**	**Prof. Practice**	**No Prof. Practice**
n	322	163	159	17	305	145	177
	M (± SD)						
(a) use digital tools for the systematic filing and permanent storage of data and information	1.45 (±1.16)	1.52 (±1.15)	1.39 (±1.17)	2.00 * (±1.00)	1.42 * (±1.16)	1.37 (±1.18)	1.53 (±1.14)
(b) use digital presentation media in a targeted and addressee-oriented manner	2.10 (±1.00)	2.13 (±0.96)	2.07 (±1.04)	2.18 (±1.07)	2.10 (±1.00)	1.99 (±1.03)	2.19 (±0.97)
(c) use digital technologies to plan and coordinate the work of individuals or groups towards a common goal	1.51 (±1.10)	1.50 (±1.08)	1.52 (±1.12)	2.06 * (±1.03)	1.48 * (±1.09)	1.38 (±1.11)	1.62 (±1.08)
(d) use digital tools to obtain information and to structure and evaluate it	2.10 (±1.03)	2.10 (±0.98)	2.09 (±1.08)	2.18 (±1.13)	2.09 (±1.02)	1.94 * (±1.08)	2.22 * (±0.97)
(e) collect data using digital technologies	1.49 (±1.07)	1.61 * (±1.04)	1.37 * (±1.08)	1.94 (±1.03)	1.47 (±1.07)	1.42 (±1.05)	1.55 (±1.08)
(f) process data using digital technologies	1.32 (±1.07)	1.50 ** (±1.06)	1.12 ** (±1.05)	1.94 * (±0.97)	1.28 * (±1.07)	1.28 (±1.06)	1.35 (±1.08)
(g) use fact-checking strategies to debunk fake news	1.48 (±1.16)	1.47 (±1.14)	1.48 (±1.18)	2.00 (±1.12)	1.45 (±1.16)	1.28 ** (±1.14)	1.64 ** (±1.15)
(h) deal with the essential aspects of data protection and data security	1.17 (±1.04)	1.18 (±1.01)	1.15 (±1.08)	1.76 * (±1.03)	1.13 * (±1.03)	1.10 (±1.03)	1.22 (±1.05)
(i) use social media as a resource for teaching-learning situations	1.44 (±1.08)	1.33 (±1.04)	1.55 (±1.11)	1.35 (±1.17)	1.44 (±1.07)	1.31 (±1.11)	1.55 (±1.04)
(j) consider copyright issues when selecting material from the Internet	1.59 (±1.09)	1.65 (±1.04)	1.52 (±1.13)	2.41 ** (±0.71)	1.54 ** (±1.09)	1.55 (±1.09)	1.61 (±1.09)
(k) choose digital media for evidence-based lesson preparation	1.64 (±1.03)	1.64 (±1.01)	1.63 (±1.06)	1.76 (±1.03)	1.63 (±1.04)	1.58 (±1.02)	1.68 (±1.04)
(l) consider the topics of technology ethics, media education, and accessibility in the classroom	0.96 (±1.00)	0.98 (±0.98)	0.93 (±1.02)	1.59 ** (±0.80)	0.92 ** (±1.00)	0.89 (±0.98)	1.01 (±1.02)
(m) plan, implement, and evaluate teaching and learning processes with digital media and learning environments	1.57 (±1.06)	1.65 (±1.06)	1.48 (±1.05)	1.82 (±0.88)	1.55 (±1.07)	1.43 * (±1.07)	1.67 * (±1.04)
(n) use digital media, software, and digital content in a subject-specific manner	1.52 (±1.05)	1.58 (±1.04)	1.47 (±1.06)	2.12 * (±0.86)	1.49 * (±1.05)	1.42 (±1.07)	1.61 (±1.02)
(o) promote the learners' digital skills	1.45 (±1.05)	1.51 (±1.06)	1.39 (±1.05)	2.06 * (±1.14)	1.42 * (±1.04)	1.30 * (±1.03)	1.58 * (±1.05)
(p) lead an efficient and responsible class and school administration	1.00 (±1.07)	0.98 (±1.04)	1.02 (±1.10)	1.00 (±1.12)	1.00 (±1.07)	0.88 (±1.03)	1.09 (±1.09)
(q) communicate and collaborate within the school community	1.61 (±1.11)	1.64 (±1.07)	1.58 (±1.15)	1.82 (±1.13)	1.60 (±1.10)	1.55 (±1.13)	1.66 (±1.08)

Table 6. *Cont.*

(r) continue my digital education independently	1.95 (±1.08)	2.01 (±1.06)	1.88 (±1.10)	2.53 * (±0.80)	1.91 * (±1.09)	1.83 (±1.13)	2.04 (±1.04)
(s) use digital tools to evaluate the level of learning	1.24 (±1.01)	1.33 (±1.02)	1.15 (±0.99)	1.88 ** (±0.99)	1.21 ** (±1.00)	1.16 (±1.03)	1.31 (±0.98)
(t) actively involve learners in the participation of the lesson using digital tools	1.61 (±1.06)	1.57 (±1.04)	1.64 (±1.08)	1.71 (±1.05)	1.60 (±1.06)	1.42 ** (±1.07)	1.76 ** (±1.03)

Note. Question, statements, and answer options have been translated from German and used a 4-point semantic differential scale ranging from insufficiently (0) to sufficiently (3). Items (a)–(k) are based on the work of Mandl et al. (2022), who built on the DiKoLAN framework (Becker et al., 2020). Items (l)–(r) are derived from the areas of the national digi.kompP framework (Brandhofer et al., 2021). Items (s) and (t) are based on competences of the DigCompEdu framework (Redecker, 2017). * $p < 0.05$. ** $p < 0.01$.

Students with professional practice felt significantly less prepared to use digital tools to manage information ($p = 0.022$), use fact-checking strategies ($p = 0.006$), and manage learning processes ($p = 0.047$). Furthermore, they felt less prepared to promote their learners' digital skills ($p = 0.017$) and actively involve them in lessons using digital tools ($p = 0.005$). H3 is accepted for the mentioned skills.

Table 7 depicts the results of the thematic analysis of the comments on the set of questions described above. Students' remarks addressed the same three main themes as in the question before but with a stronger focus on the acquisition of competences outside the university and the barriers to it. The first, less present theme mainly comprised responses highlighting that the *acquisition of digital skills at the university* is heavily dependent on the teaching subject.

The second theme that emerged shows students' opinions regarding their role in the *acquisition of digital competences outside university*. Most of the comments indicated that students have acquired the aforementioned skills through self-study rather than having them acquired at the university. A deeper analysis of the respective comments and their contexts suggests that students wish for more support, guidance, offers, exchange, and reflection concerning digital competences. One comment encapsulates this desire: "Some of these things were required in my studies, but were not 'taught'. It was just said 'do that,' we seldom or not at all reflected on this or discussed how to do it 'right."' A new code introduced to this theme adds prior knowledge to the sources of acquired digital competences outside the university.

Once again, the *barriers to the acquisition of digital skills* made up the third category. The most present category represents comments stating that there were no or hardly any digital competences taught at the university. An analysis of students' statements shows that they criticized missing support and a general lacking thematization of digitization. Additional identified barriers were the need for more concrete examples, such as designing a worksheet and applying fact-checking strategies, a lack of reference, and the faculty staff's insufficient digital competence.

Feedback and comments contains comments providing additional context and remarks to the given ratings and answers. One answer criticized the length of the questionnaire, while another answer asked for the definition of digital competence—which was provided in the introduction, but overseen.

Table 7. Thematic Analysis of Additional Comments on Students' Self-Assessed Capability to Teach Digital Skills.

"Additional comments on the block of questions above:"		
Theme/Code	**Exemplary Statement**	**Frequency**
Acquisition of Digital Competences at University		4
Acquisition dependent on teaching subject	Many of the above-mentioned things are obvious for computer science students (and possible future IT custodians) and thus maybe not representative. I believe that we also have more courses in this regard and spend more time with it in self-study.	3
A chosen few digital competences acquired at university	Only one seminar had an actual digital focus, but a lot of things were discussed there, seldom in detail	1
Acquisition of Digital Competences Outside University		24
Acquisition through self-study	I possess most of these skills and can apply them well, but I have acquired them only through independent work and not through university	17
Acquisition through teaching practice	I had to acquire a lot of it in everyday professional life	4
Prior knowledge	many of my skills come from my IT specialist studies before the teacher education program	3
Barriers to Acquisition of Digital Competences		21
Hardly any digital competences taught at university	In my opinion, the degree program did not prepare or hardly prepared for many of these aspects.	15
Desire for concrete examples	there should be specific digital practical seminars	3
Lack of competence of faculty staff	Professors themselves are often not well versed (this is NOT meant as criticism of teachers, they probably did not have a proper training in digital education themselves)	1
Lack of reference	I have the feeling to be competent in the named situations, but there are maybe additional fields I do not know or are less competent in I have not yet heard from. I can always find a way, but do I have a good/the best way?	1
Too much theory taught at university	the system is the problem, namely a university teacher education degree program lacking in practical relevance	1
Feedback and Comments		8
Questionnaire feedback and comments	I answered the questions independently from my knowledge as computer scientist. I.e. what the degree program contributed in this regard	8

Note. Question and exemplary answers have been translated from German.

4.2. Opportunities for Improvement in the Teacher Education Program

The last section of the survey addressed *suggestions for improvement*. Figure 3 and Table 8 show pre-service teachers' opinions on a selected set of digital skills. A large number of respondents were in favor of a tighter integration of nearly all of the suggested skills. Four suggestions could be seen as somewhat controversial as more than 20% did not support them, namely the creation of graphics/animations, programming and computational thinking, the use of office software, and scientific work. However, more than 80% agreed or rather agreed that the other 14 competences should play a bigger role in the teacher education program. The most wished-for competence was found to be the use of open educational resources with 92% of respondents (rather) supporting this.

Several statistical differences were found. Pre-service teachers of STEM subjects were significantly less in favor of putting a focus on the use of office software (p = 0.030), mobile applications (p = 0.047), holding online lessons (p = 0.041), and the use of free teaching materials (p = 0.018). H1 is therefore accepted for these skills.

Pre-service teachers of the subject CS significantly lower agreed to elaborate on the use of administrative software (p < 0.001) and office software (p = 0.004), dealing with subject-specific digital media (p = 0.003), holding online lessons (p = 0.006), and scientific work (p = 0.0360). H2 is supported in the case of the mentioned skills.

Students with professional practice were significantly more likely to support increasing the inclusion of the use of e-learning platforms (p = 0.003), the use of office software (p = 0.002), creating digital teaching material (p = 0.022) as well as assignments and tests (p = 0.010), and programming/computational thinking (p = 0.020), supporting H3 for the aforementioned skills.

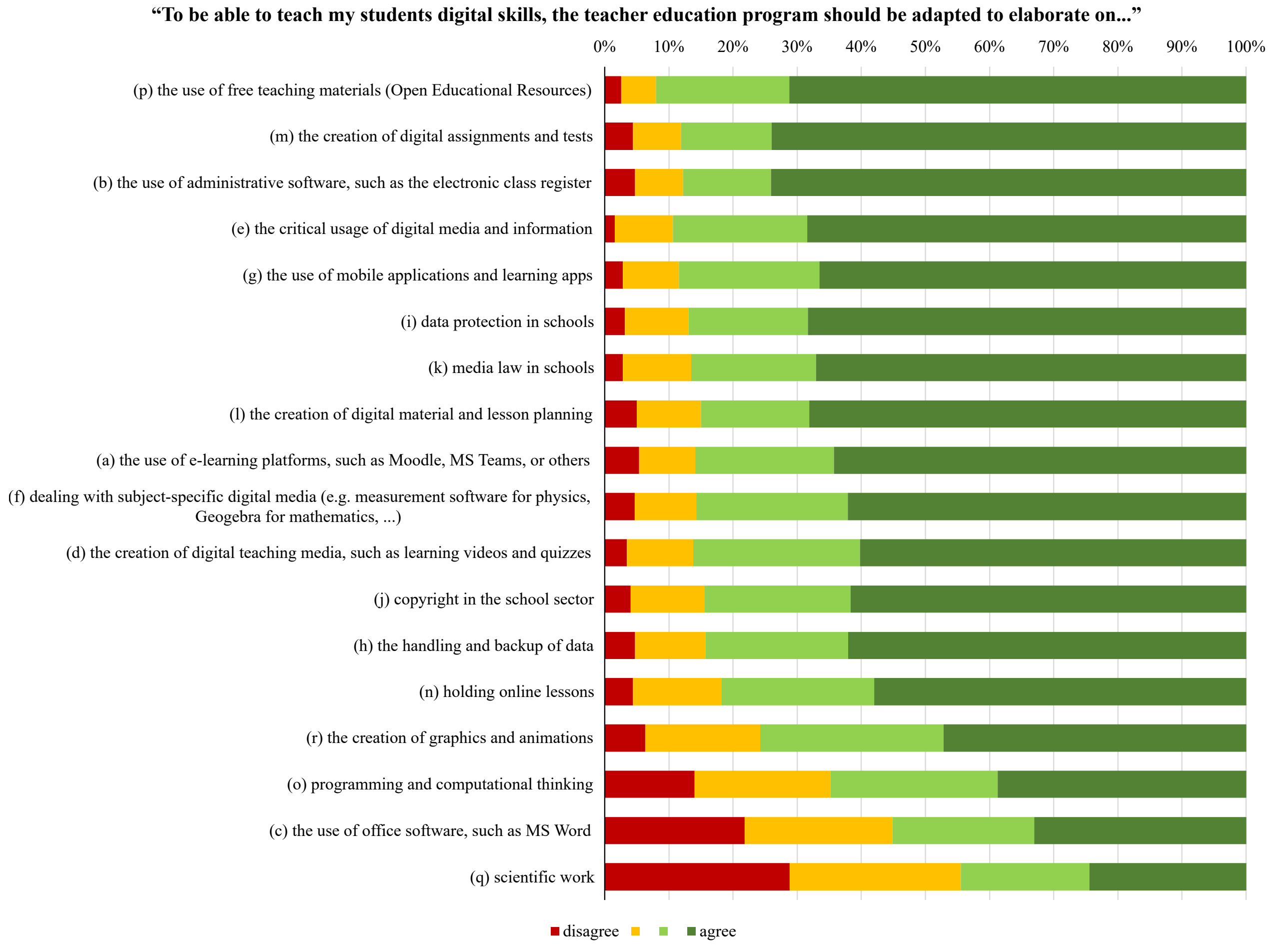

Figure 3. Bar Chart Visualizing Students' Suggestions for Improvement. *Note.* Question and answer options have been translated from German. Items were created based on authors' experience and discourse with students and each other.

The thematic analysis of students' open answers regarding suggestions for improvement can be seen in Table 9. Students' suggestions for improvement revolved around three main themes. The first and most common theme addresses the *responsible interaction with digital media*, thus complementing the otherwise sole and unreflected application of digital tools. Pre-service teachers' suggestions were to include evaluating sources, social media, digital data protection, media consumption, technology ethics, digital copyright, and internet safety in the curriculum.

Table 8. Students' Suggestions for Improvement; Grouped by Professional Practice, Subject Computer Science, and STEM Subject.

"To be able to teach my students digital skills, the teacher education program should be adapted to elaborate on…"

Statement		Total	STEM	Non-STEM	CS	Non-CS	Prof. Practice	No Prof. Practice
	n	322	163	159	17	305	145	177
		M (±SD)						
(a) the use of e-learning platforms, such as Moodle, MS Teams, or others		2.45 (±0.86)	2.39 (±0.86)	2.51 (±0.87)	2.18 (±1.01)	2.46 (±0.85)	2.59 ** (±0.77)	2.33 ** (±0.92)
(b) the use of administrative software, such as the electronic class register		2.57 (±0.82)	2.48 (±0.90)	2.66 (±0.73)	1.88 ** (±1.17)	2.61 ** (±0.78)	2.54 (±0.84)	2.59 (±0.81)
(c) the use of office software, such as MS Word		1.66 (±1.15)	1.53 * (±1.12)	1.80 * (±1.17)	0.88 ** (±0.99)	1.71 ** (±1.14)	1.89 ** (±1.13)	1.48 ** (±1.14)
(d) the creation of digital teaching media, such as learning videos and quizzes		2.43 (±0.81)	2.38 (±0.80)	2.48 (±0.82)	2.18 (±0.81)	2.44 (±0.81)	2.57 * (±0.66)	2.31 * (±0.91)
(e) the critical usage of digital media and information		2.56 (±0.72)	2.56 (±0.71)	2.57 (±0.74)	2.65 (±0.61)	2.56 (±0.73)	2.58 (±0.70)	2.55 (±0.75)
(f) dealing with subject-specific digital media (e.g., measurement software for physics, Geogebra for mathematics, …)		2.43 (±0.85)	2.38 (±0.84)	2.50 (±0.85)	2.00 ** (±0.71)	2.46 ** (±0.85)	2.53 (±0.74)	2.36 (±0.92)
(g) the use of mobile applications and learning apps		2.52 (±0.77)	2.47 * (±0.76)	2.58 * (±0.79)	2.24 (±0.90)	2.54 (±0.76)	2.59 (±0.75)	2.47 (±0.78)
(h) the handling and backup of data		2.42 (±0.86)	2.39 (±0.84)	2.45 (±0.89)	2.19 (±0.91)	2.43 (±0.86)	2.41 (±0.83)	2.42 (±0.89)
(i) data protection in schools		2.52 (±0.80)	2.50 (±0.80)	2.55 (±0.80)	2.59 (±0.62)	2.52 (±0.81)	2.48 (±0.78)	2.56 (±0.81)
(j) copyright in the school sector		2.42 (±0.85)	2.38 (±0.84)	2.46 (±0.85)	2.41 (±0.71)	2.42 (±0.86)	2.39 (±0.82)	2.45 (±0.87)
(k) media law in schools		2.51 (±0.80)	2.45 (±0.84)	2.57 (±0.75)	2.29 (±0.85)	2.52 (±0.79)	2.51 (±0.76)	2.50 (±0.83)
(l) the creation of digital material and lesson planning		2.48 (±0.87)	2.46 (±0.83)	2.51 (±0.90)	2.25 (±1.00)	2.49 (±0.86)	2.57 (±0.78)	2.41 (±0.93)
(m) the creation of digital assignments and tests		2.58 (±0.81)	2.60 (±0.75)	2.56 (±0.87)	2.29 (±1.05)	2.59 (±0.80)	2.72 ** (±0.64)	2.46 ** (±0.91)
(n) holding online lessons		2.35 (±0.88)	2.26 * (±0.92)	2.45 * (±0.83)	1.76 ** (±1.03)	2.39 ** (±0.86)	2.45 (±0.82)	2.27 (±0.92)
(o) programming and computational thinking		1.90 (±1.07)	1.90 (±1.02)	1.89 (±1.13)	2.25 (±0.93)	1.88 (±1.08)	2.06 * (±1.02)	1.77 * (±1.10)
(p) the use of free teaching materials (Open Educational Resources)		2.61 (±0.71)	2.53 * (±0.73)	2.68 * (±0.68)	2.53 (±0.83)	2.61 (±0.70)	2.67 (±0.65)	2.56 (±0.75)
(q) scientific work		1.40 (±1.14)	1.33 (±1.11)	1.47 (±1.18)	0.82 * (±0.88)	1.43 * (±1.15)	1.36 (±1.12)	1.44 (±1.16)
(r) the creation of graphics and animations		2.17 (±0.94)	2.23 (±0.91)	2.10 (±0.96)	1.76 (±1.20)	2.19 (±0.92)	2.27 (±0.87)	2.08 (±0.98)

Note. Question, statements, and answer options have been translated from German and used a 4-point semantic differential scale ranging from disagree (0) to agree (3). Items were created based on authors' experience and discourse with students and each other. * $p < 0.05$. ** $p < 0.01$.

The second emerging theme was found to be the *use of digital media in the teaching profession*. The respondents wished to learn about learning material and tools, technology access, presentation media, language-sensitive media, lifelong learning, and support for teachers. This theme is therefore about getting to know the required competences and useful tools that are needed in teaching practice.

Table 9. Thematic Analysis of Students' Additional Suggestions for Improvement.

"Did you miss any elements in the list above that should be taught in your studies to be able to teach your students digital skills? If so, which?"		
Theme/Code	**Exemplary Statement**	**Frequency**
Responsible Interaction with Digital Media		16
Evaluating sources and fact-checking	Based on which criteria can I decide whether a source is scientific/trustworthy?	5
Social media	Responsible usage of social media with current platforms (Facebook, Instagram, TikTok)	3
Digital data protection	what happens with the data, what to consider before sharing content	2
Media consumption	Media consumption, manipulation of opinions and behavior through media	2
Technology ethics	Technology ethics	2
Digital copyright	digital copyright law in general	1
Internet safety	More regarding internet safety—How do I browse the web safely?	1
Usage of Digital Media		10
Learning material and tools	elaborate on alternative learning material	3
Access to technology	simple technical offers [...], students often have no technical equipment due to financial reasons; in my school, most have just a phone	2
Presentation media	PowerPoint—creating presentations	2
Language-sensitive media	Language-sensitive offers [...], in many middle schools in Vienna there's 100% migrant background	1
Lifelong learning	Learning forever—develop learning strategies that can be always used or multiple times for the purpose of lifelong learning.	1
Support for teachers	some of the named categories above [...] would substantially simplify everyday work of a teacher (e.g., digital class register, grading criteria, grade calculation etc.)	1
Didactic Design of Courses at University		10
Desire for concrete examples	More teaching and applying than unnecessary technical and mathematical nonsense	3
More didactics	I am especially missing the didactics. E.g. I know how to save documents, but how can I teach my students this?	2
Desire for good practices	Find good ways that can be adapted if necessary	1
More guidance	Elaborating on the stated items should not—like now—happen in terms of work assignments. [...] That is a nice first step, but just "dumping" digitization in terms of assignments without any explanation is not helpful	1
More personal experiences of lecturers	It would be important to talk about [...] personal experiences of the lecturers regarding the benefits of digital skills for students.	1
More statistical connections	It would be important to talk about statistical results [...] regarding the benefits of digital skills for students.	1
Student contact desired	Seeing or hearing students during the internship would be beneficial—I was not allowed to have contact with my internship class in both subjects.	1
Feedback and Comments		19
No additional suggestions	No.	12
Questionnaire feedback and comments	I would replace "elaborate on" with "teach in the first place" in the questions	7

Note. Question and exemplary answers have been translated from German.

The third identified theme addresses concrete suggestions to improve the *didactic design of courses*. Students suggested giving more concrete examples, learning more about didactics for digital media, addressing good practices, receiving more guidance regarding the use of digital media, hearing more about lecturers' personal experiences, learning more about statistics of digital media, and having more direct contact with students, e.g., during internships. Overall, students wished for more practice and guidance in courses about digital media.

Several students explicitly stated to have no further suggestions or provided *comments* about their answers or the questionnaire.

Six students also expressed their gratitude for the initiative to tackle this issue within the scope of two additional open questions asking for feedback on the survey and general remarks. Four respondents reached out via e-mail to inform the project team about their willingness to be available for follow-up interviews and/or to state their interest in the results of the survey. Three of them took part in a succeeding focus group (Göltl et al., 2024).

5. Discussion

5.1. Main Findings and Implications

The collected quantitative and qualitative data of the 322 respondents provided deep insights into students' perspective on the integration of digital competences in the university's teacher education program and into their perceived needs regarding their professional competencies of passing on digital skills to secondary level students. This allowed to find the following answers to the research questions:

RQ1: The results showed that about half of pre-service teachers do not feel sufficiently prepared through their studies to foster their future learners' digital skills. This confirms the presumptions of prior studies (Prenner, 2020) now with a considerably larger sample size. According to modern 21st century skills frameworks, these skills should be integrated across the curriculum as they are cross-cutting concerns (Voogt & Roblin, 2012) and should be taught together with content-related knowledge and skills (Rotherham & Willingham, 2009; Silva, 2009; Valtonen et al., 2021; Voogt et al., 2013). Therefore, this finding suggests an urgent need for action to provide a modern education for teachers in the era of digitization. As digitization affects all areas of life and science, it does not suffice to teach digital competences in a single add-on one hour per week subject only. In addition to the essential basics, digital skills need to be integrated into and addressed by many teachers in multiple school subjects from different perspectives.

Most of the students reported having acquired most of their digital skills on their own and not 'through' the teacher education program. Although self-directed learning is an appreciated skill closely related to 21st century skills (Anthonysamy et al., 2020; van Laar et al., 2019), students do not seem to be happy with this high percentage of 'imposed' self-acquisition. This can be derived from their wish for better integration of digital skills in their curriculum: The majority of students think that digital skills are insufficiently covered in their study program and that those skills should play a bigger role in the general educational basics. One might argue that university is indeed a place for self-study and relies on students' self-determination (Ryan & Deci, 2000), hence students might in general see acquired competences as their accomplishment. At the same time, students' self-determination might be a mere survival strategy in this case; universities should provide sufficient background information, guidance, and practical examples to create a facilitative learning environment, ultimately wakening and meeting the learners' needs for relatedness and competence (Ryan & Deci, 2000). If universities fail to do so, some students might lose interest and/or get left behind, which would explain why about half of the students do not feel sufficiently prepared to foster their learners' digital skills. In the context of industry, a far-reaching negative consequence of teachers' struggling with digital skills is apparent: How should students be motivated for a career in or with ICT if they do not experience a positive attitude and passionate engagement with the digital world in their formative years at school?

Human- or user-centered design is widely acknowledged across several areas of product design and computing (see, e.g., the ACM/IEEE Computing Curricula 2020 (CC2020 Task Force, 2020) and Parent, 2022). Based on the research, there is no doubt that curriculum design urgently needs to follow the same design strategy and take pre-service teachers' needs into account.

Only about half of the surveyed students or less felt capable of using digital media to collect and process data, evaluate the level of learning, prepare lessons, communicate and collaborate, actively involve learners, manage the learning process, coordinate group work, administer class and school, using fact-checking strategies and social media for teaching and learning, considering copyright, data protection, security, ethics, media education, accessibility, and subject-specific matters, and promoting learners' digital skills. This indicates considerable room for improvement and confirms previous findings, such as those of Prenner (2020) as well as of Røkenes and Krumsvik (2014), who found that while there are promising approaches, the literature criticized the slow adoption of ICT in teacher education. Unfortunately, it seems that not much has changed in the last decade, such that the 'digital boost' resulting from the pandemic would present a good opportunity to push forward in this direction.

RQ2: In general, students were underwhelmed by the role digital competence plays in their studies and therefore supported a tighter integration of nearly all of the digital skills suggested in the survey. Combining the quantitative and qualitative analyses reveals that especially 'complementary' and reflective competences allowing for responsible use of digital media are lacking, including technology ethics, media education, accessibility, data protection, data security, evaluating sources, and social media. Considering that some of these topics are already taught in selected courses, such as copyright, this highlights that the development of students' digital competence within the scope of the study program is rather individual, depending on the chosen teaching subjects and elective courses. This raises the question of whether certain essential digital skills, such as the reflected use of digital media, should be integrated into the common part of the degree program—the general educational basics.

Students also wished for more support and guidance in the acquisition of these skills and, importantly, in teaching them to their students. In other words, they were asking for appropriate subject didactics of digital competencies, since several of the ways pre-service teachers used to acquire digital skills (such as watching instructional videos in English) could hardly be transferred 1:1 to very young learners. They also expressed the desire for more practical examples, a focus on responsible interaction with media, as well as open educational resources. Considering that one goal of the Teaching Digital Thinking project is the development of open educational resources, this finding is especially encouraging.

A notable identified barrier to the acquisition of digital skills was the faculty staff's digital competence. Providing appropriate opportunities for staff training and—maybe even more important—sufficient working time and incentives for training could be the first measures to foster technology adoption among faculty staff.

Further suggestions for improvement addressed the didactic design of courses. The respondents wished for more didactics for digital media, good practices, lecturers' personal experiences, learning more about statistics of digital media, and direct contact with students, e.g., during internships. These suggestions are valuable for the (re-)design of courses and should be considered in the future

H1: Only evidence supporting H1 was found, which is why it is accepted for a variety of skills. Students not studying at least one STEM subject were significantly less likely to report digital skills to be sufficiently integrated into the courses of the teacher education program, being prepared to foster learners' digital skills, having used computer programs for modeling purposes and spreadsheet programs throughout their studies, as well as feeling prepared to collect and process data using digital technologies. Students of non-STEM teaching subjects were also significantly more likely to support a tighter integration of the use of office software, mobile and learning apps, open educational resources, and online lessons in the study program.

These findings confirm the concern that especially non-STEM teachers might be at risk of missing out on certain digital skills essential for the teaching profession. For instance, the question arises whether non-STEM teachers are sufficiently prepared to perform basic tasks requiring data handling. Working as a teacher requires a fair amount of data management, including handling students' records, grading, and collecting and analyzing course feedback. The findings therefore indicate that the mandatory general educational basics and the first internships focusing on orientation do not adequately equip students with sufficient digital competences.

H2: Students of the teaching subject CS reported a significantly higher mastery in several digital skills, including using spreadsheet programs, working with augmented reality, using computer programs for modeling purposes, considering legal and ethical aspects, storing data, coordinating group work, processing data, dealing with data protection, security, media education, and accessibility, using digital media in a subject-specific manner, promoting learners' digital skills, continuing their digital education, and evaluating learning using digital tools. While the first three skill differences seem reasonable, the other skills address interdisciplinary competences that are not exclusive to CS students and would be highly relevant for all subjects. CS students also reported significantly lower support for tighter integration of the use of administrative and office software, dealing with subject-specific digital media, holding online lessons, and scientific work. H2 is therefore supported in the case of the aforementioned skills; CS teacher education students feel notably more confident in their digital skills.

H3: As only supporting evidence was found, H3 is partly accepted. Students with more professional practice felt significantly less prepared to foster their learners' digital skills and reported having acquired less of their digital skills through their studies. Significant differences could be observed in using digital media to prepare teaching content, use textbooks, obtain information, check facts, manage the learning process, actively involve learners, manage e-learning platforms, apply office software, create teaching media and tests, and program. This finding is coherent with the literature (Aslan & Zhu, 2016; Tondeur et al., 2017); however, based on dialogue with students and graduates, we rather support the interpretation of Tondeur et al. (2017) and do not hypothesize an actual difference in their digital competence, but rather interpret the phenomenon as a 'reality shock': Only after having worked on-site as a teacher, students perceive the actual requirements posed by school life, ultimately realizing what they miss. This effect may have been amplified by the pandemic since the school reality was governed by social isolation and distance education. To reach their students, teachers had to switch quickly to using digital technologies without prior preparation.

Students with professional practice were also significantly less likely to agree that the subject didactics covered more digital skills than the courses of the general educational basics. This may be another consequence of the reality shock, which could make students realize that the subject didactics also missed covering certain required digital skills or, in particular, the skills to pass on digital skills to secondary-level students. They seem to recognize the challenge to meet the individual needs of their diverse learners due to the hectic working life of a teacher and the scarcity of time, making it hard to reasonably foster their learners' digital competences and include them sufficiently in the learning process. Again, the COVID-19 crisis may have multiplied the reality shock since—without preparation—using digital media suddenly became the sole way of contact and instruction.

Finally, students with professional practice were significantly more likely to support strengthening the integration of e-learning platforms, office software, creating digital teaching material, and programming/computational thinking in the study program. These factors seem to be particularly underrepresented in the teacher education curriculum in comparison to its relevance in the teaching profession. Providing students more opportunities to gather practical experience, especially in combination with the application of digital skills in the classroom, could be a measure to reduce the impact of the practice shock.

5.2. Notes and Limitations

An evident limitation of this work is that this study presents the results of *only one university and teaching association* around the University of Vienna, a large mid-European university. The results may therefore be specific to this university and formed by the particular teacher education program, courses, faculty staff, and students. Despite this limitation, precious insights from the students' perspective were gained that in many respects corroborate with earlier work (see, e.g., Tondeur et al., 2017) and at the same time provide a fresh view of current graduates' struggles when starting their work as teachers in the time of the social and digital transformation. This is why this research is shared, hoping to contribute a piece to the current educational landscape that needs to be complemented and constantly re-evaluated internationally to accommodate for cultural and economic differences and the rapid advances in the field, such as those brought about by AI-driven tools.

Second, the *response rate* of about 8% was lower than expected, despite all efforts to increase it by sending two reminders and carefully designing the survey. The response rate of web-only surveys addressing large populations is typically rather low compared to other methods (see, e.g., Dillman et al., 2014). About half of the recipients who opened the questionnaire did not complete the survey, which was probably caused by the length of the questionnaire—75 questions and an average of 18 min to answer the survey are admittedly a lot to ask. Furthermore, students are regularly asked to participate in online surveys and may therefore be tired of answering them. In the case of college surveys, Fosnacht et al. (2017) found that for large sample frames (i.e., more than 500 surveyed students), response rates of 5%–10% typically still deliver reliable results. In any case, the resulting 322 complete responses of the sample frame of 4054 are considered to constitute a fair sample size that allowed for interesting insights and statistical analyses.

Third, this study did *not use random sampling* and may therefore be subject to selection bias—students who did not respond could not share their opinion and may have different characteristics that remain unseen. Random sampling would not have been reasonable in this case, as randomly selecting recipients would have lowered the response rate even more. However, as mentioned in previous work (Ambros et al., 2022), two authors of this paper are also active teachers of the teacher education program and can confirm that, based on their experience, the answers and results of this study reflect students' general opinions well. Furthermore, a focus group with pre-service teachers that confirmed this work's findings was conducted (Göltl et al., 2024).

Finally, this study used a *self-report instrument*. Hence, only students' *perceived* ability to foster digital competence could be observed and discussed and not their objective ability to do so. The measurement of digital competence and its challenges are the subject of ongoing research (see, e.g., Maderick et al., 2016) and should be further extended in the future. The goal of this study was not to measure students' actual digital competence, but rather to gain feedback on the pre-service teachers' perceived situation and to grasp their attitude towards digital skills. The latter was found to have a significant impact on the use of ICT in class (Drossel et al., 2017). In a nutshell, despite inherent limitations, the applied research instrument allowed to answer the posed research questions as reliably as possible under the inherent constraints. Like-minded researchers are invited to use and adapt the instruments to help in getting a larger picture of the landscape of digital skills forming an essential share in the capacities to handle current and future challenges.

Several precautions were taken to avoid any harm that could arise from taking part in the survey. First, participation was voluntary; there was neither an advantage nor disadvantage for answering the questionnaire. Second, the identities of students were unknown to the authors at all times during the study. Finally, the surveyed demographic data were kept at a minimum to protect students' identities and focused only on the information relevant to the research questions. For instance, students were not asked to disclose their gender, as the combination of gender, semester, and subject might allow one to infer students' identities.

5.3. Recommendations

Based on the evidence, this research proposes the following ten suggestions to foster the development of digital skills and the mediation of them within the scope of the teacher education program:

1. *Raising awareness* of the importance of digital skills in teacher education on-site and involving multiple key stakeholders, such as study program directors, responsible leadership, and authorities (e.g., by disseminating the results of the survey)
2. Tighter integration of basic digital skills as a *cross-cutting concern throughout the curriculum*. Strengthening of self-regulation capacities in acquiring digital competences along with reflective practice.
3. Broader offer of *elective courses* on digital skills to allow for specialization
4. *More teaching practice*, especially in combination with digital skills, in the study program to help reduce the reality shock, e.g., getting used to work with administrative tools
5. *Didactic redesign of courses* to provide more guidance on and examples of mediating digital skills to learners
6. Offers for *staff training* regarding digital skills along with incentives
7. Initiation and active promotion of *communities of practice and significant learning communities* (Motschnig-Pitrik, 2008) for digital empowerment in teacher education to foster interdisciplinary exchange across teaching subjects, in which STEM and CS teachers may act as multipliers
8. Development of *open educational resources and good practices* that serve as anchor points for pre-service and in-service teachers (see, e.g., Ambros et al., 2024)
9. *Cooperation at various levels* among multiple actors, such as universities' teaching support centers, IT support, in-service teachers, and mentors
10. Observing and *continuing research on digital skills* in an international context to be up-to-date, especially on AI competence

Given that institutes of teacher education seem to face the same challenges worldwide (see, e.g., Gudmundsdottir et al., 2014; Maderick et al., 2016; Aslan and Zhu 2016; Tondeur et al., 2017), these recommendations may be discussed and adapted to an international context.

6. Conclusions

This contribution analyzed the responses of 322 teacher education students to a 75-question survey on the integration of digital competence in the study program. About half of our pre-service teachers did not feel sufficiently prepared through their studies to foster their future learners' digital competence. Moreover, a majority of students see their acquired digital skills more as an accomplishment of themselves than having learned them at the university. Furthermore, we found that the courses of the teaching subjects cover more digital skills than the general educational basics. The acquisition of digital competence heavily depends on the students' chosen teaching subjects and elective courses; especially non-STEM students are at risk of missing out on essential digital skills, such as handling data and using office software. We also found evidence of a 'reality shock' or 'practice shock'. Further work includes complementing the results by focus groups with students, which have already been conducted and evaluated (Göltl et al., 2024), providing additional interesting insights into students' perception of their own digital competences. Moreover, rapid advances in powerful, generative AI-driven technologies are posing new challenges and opportunities requiring thoughtful and evidence-based adaptations of digital skills frameworks and curricula, opening up exciting new questions for research, practice, and their synergies.

Overall, we conclude and believe that digital skills are currently spread at schools by individual 'digital enthusiasts' (see, e.g., Røkenes and Krumsvik, 2016); a systematic strategy and commitment to digital skills as an integral part of teacher education still seems to be missing and long overdue. Digital competence is an essential part of the modern skill set required in the 21st century and is expected to be taught at school. Hence, universities should not only focus on mediating subject-specific knowledge (CC2020 Task Force, 2020) but also develop and thoughtfully implement a holistic, and flexibly adaptable concept to integrate digital skills in the teacher education curriculum such that every graduate will act as a skilled representative of the social and digital transformation in education.

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Institutional Review Board Statement: The study was carried out in accordance with national law. Participation in the university-wide survey was anonymous and voluntary. The participants were informed about the purpose of the survey and how their provided answers will be used before giving their consent. To guarantee conformity with the university's guidelines for data protection and privacy, the university entities Quality Assurance, Teaching Affairs and Student Services, the Center for Teaching and Learning, the works committee, and the Rectorate were consulted, which gave the final permission to conduct the survey.

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Note

[1] In this article, *skill* and *competence* are used interchangeably to streamline the text and improve readability.

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