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Perceived ICT-Related Learning Opportunities During Teacher Education and Pre-service Teachers' Perceptions of Outcomes of the Use of ICT for Teaching and Learning and Their Uncertainty Tolerance Regarding the In-classroom Use of ICT*

Abstract

We examined perceptions of ICT-related learning opportunities during teacher education, perceived outcomes of the use of ICT for teaching and learning and uncertainty tolerance regarding the in-classroom use of ICT in a sample of 131 pre-service teachers. Results from two-step cluster analyses identified two groups based on participants' perceptions of ICT-related learning opportunities: Participants in cluster 1 overall reported higher values for most indicators than participants in cluster 2. Participants' perceptions of outcomes of the use of ICT for teaching and learning and their domain-specific uncertainty tolerance did not vary significantly between clusters. In the total sample, there was a significant positive correlation between participants' perceptions of positive outcomes of the use of ICT for teaching and learning and their uncertainty tolerance and significant negative associations between perceived negative outcomes of the use of ICT for teaching and learning and perceived positive outcomes and their uncertainty tolerance. Significant and similarly directed associations were found in cluster 1 but not in cluster 2. Correlations between perceived positive and negative outcomes of the use of ICT for teaching and learning and between perceived negative outcomes of the use of

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ICT for teaching and learning and participants' uncertainty tolerance differed significantly between clusters.

Keywords
Perceived ICT-related learning opportunities; Pre-service teachers; Teacher education; Perceived outcomes of the use of ICT for teaching and learning; Uncertainty tolerance

Wahrgenommene digitalisierungsbezogene Lerngelegenheiten während der Lehramtsausbildung und Einschätzungen von Lehramtsstudierenden zu Folgen digital gestützten Unterrichts und ihre Ungewissheitstoleranz in Bezug auf den unterrichtlichen Einsatz digitaler Medien

Zusammenfassung
In dieser Studie wurden Einschätzungen angehender Lehrkräfte zu digitalisierungsbezogenen Lerngelegenheiten während der Lehramtsausbildung sowie zu Folgen eines digital gestützten Unterrichts und ihrer Ungewissheitstoleranz in Bezug auf die unterrichtliche Nutzung digitaler Medien in einer Stichprobe von 131 Lehramtsstudierenden untersucht. Ergebnisse von two-step Clusteranalysen deuten auf zwei Gruppen basierend auf der Wahrnehmung digitalisierungsbezogener Lerngelegenheiten hin: Teilnehmende in Cluster 1 berichteten insgesamt für die Mehrheit an Indikatoren stärker ausgeprägte Werte als Teilnehmende in Cluster 2. Einschätzungen zu Folgen des unterrichtlichen Einsatzes digitaler Medien und der bereichsspezifischen Ungewissheitstoleranz variierten nicht signifikant zwischen den Clustern. In der Gesamtstichprobe gab es eine positive Korrelation zwischen Einschätzungen zu positiven Folgen des unterrichtlichen Einsatzes digitaler Medien und der Ungewissheitstoleranz der Teilnehmenden und signifikante negative Korrelationen zwischen Einschätzungen zu negativen Folgen des unterrichtlichen Einsatzes digitaler Medien und eingeschätzten positiven Folgen sowie der Ungewissheitstoleranz der Teilnehmenden. Entsprechend gerichtete signifikante Korrelationen ließen sich in Cluster 1, nicht jedoch in Cluster 2 identifizieren. Korrelationen zwischen eingeschätzten positiven und negativen Folgen des unterrichtlichen Einsatzes digitaler Medien und zwischen Einschätzungen zu negativen Folgen des unterrichtlichen Einsatzes digitaler Medien und der Ungewissheitstoleranz in Bezug auf die unterrichtliche Nutzung digitaler Medien variierten signifikant zwischen den Clustern.

Schlagworte
wahrgenommene digitalisierungsbezogene Lerngelegenheiten; Lehramtsstudierende; Lehramtsausbildung; eingeschätzte Folgen des unterrichtlichen Einsatzes digitaler Medien; Ungewissheitstoleranz

1. Introduction

Digitization is moving forward quickly in many domains of life (OECD, 2019). Integrating information and communications technology (ICT) into school education therefore is crucial in at least to regards, referring to both, the ICT-assisted "teaching task" (Krauskopf et al., 2018, p. 155), on which the present study focuses, as well as to promoting students' digital literacy (Fraillon, 2025). The implementation of ICT into schools was at least temporarily catalyzed by the Emergency Remote Teaching during the COVID-19 pandemic (Howard et al., 2021a) and proportions of in-service teachers who use ICT for teaching on a daily basis have increased relevantly between 2018 and 2023 in many contexts according to results from the International Computer and Information Literacy Study (ICILS) (Drossel et al., 2019, 2024). Yet, many pre-service teachers and in-service teachers still perceive teaching with digital media as a challenge (Niu et al., 2021; OECD, 2019). All the more, it is important that an appropriate preparation for this task starts already at an early point of pre-service teachers' professional development during teacher education (Howard et al., 2021b; KMK, 2016/2017). The present paper examines how pre-service teachers in the underlying sample perceived the availability of ICT-related learning opportunities during their teacher education so far, their self-reported use of and satisfaction with such learning opportunities as well as their perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT and associations between these factors.

1.1 (Perceived) ICT-related Learning Opportunities for (Pre-service) Teachers

ICT-related learning opportunities in the context of teacher education and professional development are often assessed through pre- or in-service teachers' *perceptions* of such learning opportunities, which are subjective but still highly relevant indicators. Current examples can, for example, be found in the context of the ICILS 2023 (Drossel et al., 2024): The results showed that 33.9 per cent of the participating in-service teachers at secondary schools in Germany reported that general approaches toward the use of ICT to improve teaching and learning processes had been part of their teacher education (Drossel et al., 2024; international average: 46.8%; average in the European reference group: 41.1%). 31.8 per cent of them reported that subject-specific approaches toward using ICT to improve teaching and

learning processes had been part of their teacher education (Drossel et al., 2024; international average: 42.0%; average in the European reference group: 37.2%). 22.4 per cent of them reported that handling social problems that students might experience in the context of using ICT for communicative purposes had been part of their teacher education (Drossel et al., 2024; international average: 29.3%; average in the European reference group: 22.6%). 22.4 per cent of them reported that the use of ICT for collaboration with other teachers had been part of their teacher education (international average: 38.5%; average in the European reference group: 32.6%). Only 13.6 per cent of them reported that using ICT for assessing students' competencies had been part of their teacher education (international average: 38.0%; average in the European reference group: 30.1%). Evidently, these figures from in-service teachers at secondary schools in Germany were all below international average and below the average from the European reference group. However, results from age-specific analyses from the German subsample showed that, for example, the percentage of participants who reported that general approaches toward the use of ICT to improve teaching and learning processes had been part of their teacher education was relevantly higher (65.8%) in the group of teachers who were 35 years old or younger at the point of data collection, i. e., who had completed initial teacher education rather recently (Drossel et al., 2024).

There is a wide range of empirical evidence supporting the assumption that ICT-related learning opportunities can have a relevant impact on the development of pre-service teachers' competencies or self-estimated skills for ICT-assisted teaching (for example, Hülshoff et al., 2024; Banas & York, 2014; Lee & Lee, 2014; Mouza et al., 2014; Polly et al., 2010; Tondeur et al., 2018; Valtonen et al., 2015). However, in this context, further elaboration on the concept of "learning opportunities" (hereinafter: "LO") is crucial: Conceptual distinctions between *formal* and *informal* LO that can be found, for example, in earlier literature on workplace learning or lifelong learning (for example, Conlon, 2004; Eraut, 2004; Jacobs & Park, 2009; Werquin, 2010; Williams, 2003) have lately more and more been applied in research on (pre-service) teachers' learning processes and professional development (for example, Colognesi et al., 2020; Richter et al., 2011; Yu et al., 2021). Tachtsoglou and König (2018) even distinguish between three types of LO within the context of teacher education: *formal* LO that refer to institutionalized educational establishments that allow for qualified degrees, *informal* LO that refer to learning processes in everyday life which are not necessarily recognized as such by learners and *non-formal* LO that refer to not explicitly formalized learning processes. In a similar but slightly different fashion, Röhl et al. (2024) distinguish between *formal* LO (LO with a high degree of organizational specifications; see also Eurostat, 2016), *informal* LO (LO outside of organized events and curricular requirements; see also Cerasoli et al., 2018) and *incidental* LO (for example, unintentional/unwitting learning processes; see also Marsick & Watkins, 2001). However, such LO may at times blur and definitions of formal, informal and non-formal or incidental learning processes vary in the literature (see, for example, Manuti et al., 2015; Röhl

et al., 2024). Hereinafter, we therefore distinguish between pre-service teachers' *academic*, *school practical* and *everyday life* ICT-related LO (see also Hülshoff et al., 2024). Moreover, it is assumed that it is not alone the mere availability of LO that is relevant for (pre-service) teachers' development, but a complex interplay between (perceived) LO offers and their use (Voss et al., 2015). Furthermore, in the past few years, aspects of students' satisfaction in the context of learning processes have repeatedly been emphasized (for example, Jansson et al., 2019; Oldervik & Lagestad, 2021). In the context of the project "Digitalisierungsbezogene Lerngelegenheiten in der Lehramtsausbildung (DiLeLa)" (Hülshoff et al., 2024), to which the analyses presented in this paper refer, we therefore focused on the perceived availability of ICT-related LO during teacher education but also on pre-service teachers' self-reported use of such LO and their satisfaction with such LO.

In a secondary analysis based on data from the ICILS 2013, Drossel and Eickelmann (2017) used latent class analysis to identify different groups of teachers in the context of internal ("further training within the school setting", p. 2) and external ("external training activities", p. 2) ICT-related professional development, comparing two-, three-, four- and five-group-solutions to one another. Findings based on the German subsample indicated the best fit for the two-group-solution. The two identified groups were quite opposed to one another: A group of teachers with "a strong tendency to participate primarily in internal professional development activities, but also in external development" and another group with a teacher type that "hardly participates in any professional development, be it external or internal" (Drossel & Eickelmann, 2017, p. 8). Drossel and Eickelmann (2017, p. 8) refer to the first group as "inclined to professional development" and to the latter as "professionally undeveloped". It needs to be noted, though, that their study refers to *in-service* teachers.

However, there are several studies focusing on *pre-service* teachers in the context of ICT-assisted teaching and learning that found two-group-solutions that, overall, appeared diametrically opposed to one another, too: Findings from cluster analyses by Pozas et al. (2024) identified two groups in a sample of 155 initial teacher education students from two public universities in Germany. Pre-service teachers in cluster 1, on average, reached significantly higher values regarding ICT-related attitudes and significantly lower values regarding ICT-related concerns (Pozas et al., 2024). Scores regarding ICT-related self-concept and self-efficacy in that cluster were about the general average for these constructs (Pozas et al., 2024). Pozas et al. (2024, p. 246) refer to this group as "Can-do-ICT type". Pre-service teachers in cluster 2, by contrast, reported on average significantly stronger ICT-related concerns and reached rather low values regarding their ICT-related self-concept and self-efficacy, but rather moderate values regarding ICT-related attitudes (Pozas et al., 2024). Pozas et al. (2024, p. 246) refer to this group as "Discouraged-ICT type". Results from a two-step cluster analysis by Jin and Schmidt-Crawford (2022, p. 3) also identified a two-group-solution in a sample of 1246 pre-service teachers from a "large Midwestern land-grant university" with two groups that, overall, appeared

fairly opposed to one another. A central focus of the study was on participants' "Technological Pedagogical Content Knowledge" (TPACK) (Jin & Schmidt-Crawford, 2022). Pre-service teachers in cluster 2 reached higher TPACK scores at all times of measurement than pre-service teachers in cluster 1. However, neither in the study by Pozas et al. (2024) nor in the study by Jin & Schmidt-Crawford (2022) was cluster allocation primarily based on (perceptions of) ICT-related LO during teacher education, which is why further examination within this field constitutes an important research desideratum.

1.2 Perceptions of Positive and Negative Outcomes of the Use of ICT for Teaching and Learning and Uncertainty Tolerance Regarding the In-classroom Use of ICT

Pre-service teachers' attitudes related to ICT-assisted teaching have often been shown to be relevant predictors for their technology acceptance regarding their future teaching (Teo, 2009, 2010). Such attitudes may, for example, comprise (pre-service) teachers' perceptions of the utility of ICT for teaching purposes as well as their perceptions of costs that might come with including ICT into their (future) teaching (Hülshoff & Jucks, 2024; Teo, 2009, 2010). The ICILS refers to "perceptions of positive and negative outcomes of using ICT for teaching and learning" (Fraillon et al., 2020, p. 204). Perceptions of positive outcomes might, for example, include beliefs that the use of ICT for teaching and learning "improves academic performance of students" or "helps students develop skills in planning and self-regulation of their work" (Fraillon et al., 2020, p. 205). Perceptions of negative outcomes, by contrast, might comprise beliefs that the use of ICT for teaching and learning "results in students copying material from internet sources" or "results in poorer written expression among students" (Fraillon et al., 2020, p. 205).

Another relevant predictor – besides from other important factors such as, for example, curricular frameworks, facilitating conditions and skills – of in-service and possibly also pre-service teachers' approaches toward ICT-assisted teaching is their uncertainty tolerance regarding the in-classroom use of ICT (Hülshoff et al., 2025; Gerick & Killus, 2024). "Uncertainty tolerance" (or "ambiguity tolerance") is a psychological construct that refers to interindividual differences as to how people deal with complex and meaningful situations which seem hard to control and when outcomes appear unclear (Friedel & Dalbert, 2003; König & Dalbert, 2004; see also Hülshoff et al., 2025). While people with a (rather) low degree of uncertainty tolerance perceive such situations (primarily) as a threat and therefore try to avoid them, people with a higher degree of uncertainty tolerance are more likely to perceive such situations as a challenge or even as an opportunity (Friedel & Dalbert, 2003; König & Dalbert, 2004; see also Hülshoff et al., 2025). A certain level of uncertainty tolerance has often been interpreted as an important prerequisite of peoples' mental well-being and resilience (Friedel & Dalbert, 2003; König & Dalbert, 2004; Strout et al., 2018; see also Hülshoff et al., 2025) as it might add to a more

prudent and balanced information processing (Friedel & Dalbert, 2003; König & Dalbert, 2004; Sorrentino et al., 1988; see also Hülshoff et al., 2025). The concept of uncertainty tolerance has been applied to the school context in general several times (for example, Bauer, 2019; Friedel & Dalbert, 2003; König & Dalbert, 2004) and lately specifically to the context of ICT-assisted teaching, too (Hülshoff et al., 2025; Gerick & Killus, 2024; Vennemann et al., 2021). Results from a secondary analysis by Gerick and Killus (2024) based on the German ICILS 2018 subsample showed that the uncertainty tolerance regarding the in-classroom use of ICT of the participating in-service teachers at secondary schools in Germany positively correlated with their reported use of ICT for teaching.

Perceptions of positive outcomes of ICT-assisted teaching or the utility of the use of ICT for teaching on the one hand and perceptions of negative outcomes of ICT-assisted teaching or costs that might come with including ICT into teaching on the other hand tend to be negatively associated with one another (Fraillon et al., 2019; Hülshoff & Jucks, 2024). Positive value beliefs regarding the use of ICT for teaching and learning tend to be positively associated with pre-/in-service teachers' uncertainty tolerance regarding the in-classroom use of ICT (Hülshoff et al., 2025; Gerick & Killus, 2024), while reverse associations could be shown regarding negative value beliefs and uncertainty tolerance regarding the in-classroom use of ICT (Hülshoff et al., 2025).

While research findings have repeatedly supported the assumption that ICT-related LO during teacher education may have a relevant impact on the development of respective skills or self-estimated competencies of pre-service teachers (for example, Hülshoff et al., 2024; Banas & York, 2014; Lee & Lee, 2014; Mouza et al., 2014; Polly et al., 2010; Tondeur et al., 2018; Valtonen et al., 2015), so far, there is less and particularly less consistent evidence regarding potential effects of such LO on pre-service teachers' value beliefs regarding potentials and challenges (or assumed positive and negative outcomes) related to the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT. In this context, it should be noted that individuals' beliefs are often assumed to be generally changeable, although they often tend to be rather stable and inducing persistent attitude change has been shown to be fairly ambitious (Cook & Flay, 1978; Fives & Buehl, 2012; Guse et al., 2023; Rach, 2023). Related previous empirical research has, inter alia, led to the following results: Valtonen et al. (2015) found indicators for positive effects of a 12-week course on pre-service teachers' self-efficacy and subjective norms regarding teaching with digital media, but (other) beliefs and intended behavior did not change in a relevant way. Results from a study by Lachner et al. (2021) implied a positive impact of technological pedagogical content knowledge (TPACK)-modules on future teachers' self-efficacy in the context of ICT-assisted teaching, while they did not find evidence for a positive impact on perceived utility-value and enthusiasm regarding the matter. In two experiments, Backfisch et al. (2024) did not identify evidence supporting the assumption of relevant effects of two utility-value interventions on prospective teachers' utility-value perceptions,

while there was evidence hinting at positive effects on knowledge integration processes. Still, an impact of ICT-related LO on pre-service teachers' perceptions of positive and negative outcomes of the use of ICT for teaching and learning generally seems possible, provided that (prospective) teachers' profession-related views are interpreted as generally changeable (Hülshoff & Jucks, 2024).

Uncertainty tolerance has often been treated as a (rather) stable personality trait and therefore primarily as an independent variable (see Hillen et al., 2017, for an overview). However, it has implicitly or explicitly been argued that a stronger focus on (changeable) state characteristics may be justified (particularly) when the construct is conceptualized in a more area or domain specific manner (Hülshoff et al., 2025; Durrheim & Foster, 1997; Hillen et al., 2017) (in the present context: uncertainty tolerance regarding the in-classroom use of ICT). Findings by Hülshoff et al. (2025) partly support the assumption that LO during teacher education might have a relevant impact on pre-service teachers' uncertainty tolerance regarding the in-classroom use of ICT. However, further examination is needed here, too. Also, so far, it is rather unclear in what regard (perceived) ICT-related LO during teacher education might affect the interplay between pre-service teachers' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT. One possible assumption is that LO perceived as very intense and/or positive weaken associations between pre-service teachers' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT since these LO may have a positive impact on their (self-estimated) competencies for ICT-assisted teaching (Hülshoff et al., 2024), which might strengthen their confidence regarding the integration of ICT into their teaching.

2. Research Questions and Hypotheses

Against this backdrop, we examined the following research questions (RQ):

1. How can pre-service teachers in the underlying sample be grouped into different clusters based on their ICT-related learning experience during their teacher education so far (referring to perceived availability and self-reported use of and satisfaction with academic, school practical and everyday life ICT-related LO) and how do participants in these clusters differ from one another with regard to their respective perceived learning experiences?
2. Do participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT vary depending on cluster allocation?
3. How are participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the

in-classroom use of ICT associated with one another and do such correlations vary depending on cluster allocation?

RQ 1 was examined on an exploratory basis. Regarding RQ 2, we expected that participants in a cluster of pre-service teachers who perceived ICT-related LO during their teacher education so far as more intense or positive would, on average, report higher values regarding perceived positive outcomes of the use of ICT for teaching and learning and for uncertainty tolerance regarding the in-classroom use of ICT but lower values regarding perceived negative outcomes of the use of ICT for teaching and learning than participants who perceived such LO as less intense or more negative. Regarding RQ 3, we expected a positive correlation between participants' perceptions of positive outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT and negative correlations between these variables and participants' perceptions of negative outcomes of the use of ICT for teaching and learning. We expected to find such correlations in all clusters but expected smaller correlations between perceived outcomes of the use of ICT for teaching and learning and participants' uncertainty tolerance regarding the classroom use of ICT among pre-service teachers who reported more intense and positive perceptions of ICT-related learning experiences.

3. Method

3.1 Participants

The present study uses data from the project "Digitalisierungsbezogene Lerngelegenheiten (DiLeLa)" (see Hülshoff et al., 2024, for first empirical results from the project context). Within the project context, we invited pre-service teachers enrolled in master teaching degree programs at universities in the German federal states North Rhine-Westphalia and Lower Saxony to take part in an online survey about their perceptions of ICT-related LO during their teacher education so far, certain ICT-related beliefs and self-reports as well as socio-demographic and education-related background characteristics. Only pre-service teachers who were at least 18 years old and who were being trained to become teachers at *Gymnasien* (grammar schools) or *Gymnasien and Gesamtschulen* (grammar and comprehensive schools) could participate so that a homogenous sample in this regard was realized. Also, only pre-service teachers who had completed at least one official teaching placement within the context of their master teaching program prior to the survey were addressed since participation in the survey required a certain amount of school practical experience.

For sample recruitment, we contacted teacher educators at four different German universities (two in Lower Saxony, two in North Rhine-Westphalia) who passed the survey link to pre-service teachers at their respective university. It should be noted that regulating frameworks and conditions for initial teacher ed-

ucation vary between federal states and universities. However, due to terms and conditions of data collection, the underlying data set of the present study does not allow for group comparisons between participants from different federal states or different universities. A positive vote (identification code: 2022-36-AH) from the ethics committee of the Faculty of Psychology/Sport and Exercise Sciences of the University of Münster had been obtained prior to data collection. Data collection was carried out via SoSci Survey (Leiner, 2019) from 19 August through 15 November 2022. Participation was voluntary, based on participants' informed consent and fully anonymous. Overall, 186 people gave their informed consent in participation. After excluding two cases with invalid responses as well as participants who did not complete the survey and/or did not eventually provide consent with the scientific analysis of their data at the end of the survey, a total sample of $N = 131$ pre-service teachers (78.6% female, 19.8% male, 1.5% diverse; mean age = 24.66 years, $SD = 2.05$) remained (see also Hülshoff et al., 2024).

Since future secondary school teachers in Germany usually study at least two different (school) subjects at university, we asked participants to choose one of their subjects (reference) subject) and to relate their answers to it. More than half of the participants (50.4%) referred to a subject from the field of *languages* (German, English, French, Latin, Spanish), 20.6 per cent referred to a subject from the field of *mathematics, natural sciences and computer science* (biology, chemistry, computer science, mathematics, natural sciences), 16.8 per cent referred to a subject from the field of *humanities and social sciences* (geography, history, educational science, politics/politics and economics) and 12.2 per cent referred to a subject from another field (religious education, art, music, philosophy/practical philosophy, PE, other) (see also Hülshoff et al., 2024)[2]. Referring to their reference subject, participants were on average overall in the seventh or eighth semester ($M = 7.73$, $SD = 3.39$) at the time of data collection (see also Hülshoff et al., 2024). Beyond the general participation requirement of having completed at least one official teaching placement within the context of their master teaching program prior to the survey, all participants also reported that they had overall completed at least one official teaching placement with the opportunity to effectively teach their reference subject.

3.2 Measures

3.2.1 Perceived ICT-related LO

Participants' perceptions of ICT-related LO in their teacher education up to the point of data collection were measured with twelve indicators (Hülshoff et al., 2024; see the following subsections for further specification). These comprised the three domains of perceived "Academic ICT-related LO", "School practical ICT-related LO" and "Everyday life ICT-related LO". Each domain comprised measures for the per-

2 This classification is loosely inspired by an approach by Vennemann et al. (2021).

ceived availability of LO, self-reported use of available LO and satisfaction with perceived LO. Results from correlational analyses showed that some of these factors were relevantly associated with one another (Table 5 in the appendix). However, strong correlations ($r \geq .50$) could only be observed *within* said domains (for example, between different aspects of the perceived availability of ICT-related academic LO) (Table 5). Across domains – if at all –, only small to moderate correlations ($.10 \leq r < .50$) could be observed (for example, regarding satisfaction with the respective LO) (Table 5). Therefore, sufficient convergent and divergent validity (Döring, 2023) was assumed. All scales used to measure participants' perceptions had a sufficient internal consistency (see the following subsections; see also Hülshoff et al., 2024). Prior project results indicated a significant concurrent validity (Döring, 2023) for a great majority of indicators on academic and school practical level regarding participants' perspectives on ICT-assisted teaching (Hülshoff et al., 2024).

Perceptions of academic ICT-related LO

Perceived availability of ICT-related LO in university courses (for example, seminars, lectures) in the context of teacher education programs was measured with the two scales "teaching" (hereinafter: "academic LO – perceived availability I", 6 items, $a = .89$) and "guidance" ("academic LO – availability II", 6 items, $a = .82$), which were derived from the *European Framework for the Digital Competence of Educators* (*DigCompEdu*; Redecker; 2017) and its German translation (Goethe-Institut e.V., 2019). Participants were asked to rate how intensely aspects such as "use of classroom technologies to support instruction" (*teaching*) and "interaction with learners in digital environments" (*guidance*) had – as perceived – been treated in the course of their teacher education at university up to the point of data collection (including completed bachelor teaching degrees and possible changes of university as well as master teaching degrees in which they were enrolled when data collection took place) (1 = not at all, 4 = very intensely). Moreover, two single items were used to ask participants to rate how intensely they had used such LO ("academic LO – self-reported use") so far where ever the decision was up to them (for example, choice of elective subjects/modules, preparation and follow-up) (1 = not at all, 4 = very intensely) and to indicate how much they agree to be satisfied with such LO (1 = does not hold true at all, 4 = fully holds true) ("academic LO – satisfaction").

Perceptions of school practical ICT-related LO

We used one single item ("school practical LO – perceived availability") to ask participants to rate the perceived availability of opportunities to use ICT in their own teaching and/or to exchange ideas on ICT in schools and classrooms with mentor (in-service) teachers or fellow pre-service teachers (1 = never, 4 = often) during official teaching placements they had completed in the course of their teacher edu-

cation programs up to the time of data collection. Moreover, we adapted the two scales "teachers' use of ICT for teaching practices in class" ("school practical LO – self-reported use I", 8 items, $a = .84$) and "teachers' perceptions of the collaboration between teachers using ICT" ("school practical LO – self-reported use II", 5 items, $a = .84$) from the ICILS 2018 (Fraillon et al., 2020; Vennemann et al., 2021) in order to measure the extent to which the participants reportedly had used such LO so far. Participants were, for example, asked to rate how often they had used ICT to support classroom discussion in their own teaching or how often they had discussed potentials of ICT for certain subject-related topics with other prospective teachers or with in-service teachers so far (1 = never, 4 = often). Finally, we used one single item to ask participants to indicate how much they agree to be satisfied with such LO (1 = does not hold true at all, 4 = fully holds true) ("school practical LO – satisfaction").

Perceptions of everyday life ICT-related LO

We used one single item ("everyday life LO – perceived availability") to ask participants to rate the perceived availability of opportunities to learn something about ICT in their everyday life since they first enrolled in a teacher education program at university (1 = never, 4 = often). Moreover, we adapted the scale "students use of ICT for social communication" ("everyday life LO – self-reported use I", 7 items, $a = .69$) from the ICILS 2018 (Fraillon et al., 2020; Vennemann et al., 2021) and the scale "ICT as a topic of social interaction" ("everyday life LO – self-reported use II", 5 items, $a = .75$) from PISA 2015 (Mang et al., 2019) in order to measure the extent to which the participants had used such LO so far. Participants were, for example, asked to rate how often they had posted images or videos online on social platforms or how often they had exchanged ideas on digital devices with friends (1 = never, 4 = often). Finally, we used one single item ("everyday life LO – satisfaction") to ask the participants to indicate how much they agree to be satisfied with such everyday life LO (1 = does not hold true at all, 4 = fully holds true).

3.2.2 Perceptions of Positive and Negative Outcomes of the Use of ICT for Teaching and Uncertainty Tolerance Regarding the In-classroom Use of ICT

On the level of value beliefs or attitudes, we measured participants' perceptions of assumed positive (see also Hülshoff et al., 2024) and negative outcomes of the use of ICT for teaching and learning. Further, we measured participants' uncertainty tolerance regarding the in-classroom use of ICT.

Perceived outcomes of the use of ICT for teaching and learning

We used the two scales "perceptions of positive outcomes when using ICT in teaching and learning" (7 items, $a = .77$) and "perceptions of negative outcomes when using ICT in teaching and learning" (6 items, $a = .74$) from the ICILS 2018 (Fraillon et al., 2019, 2020; Vennemann et al., 2021) to assess participants' perceptions of outcomes of the use of ICT in compulsory school education. Participants were asked to rate to what extent statements such as "The use of ICT for teaching and learning helps students develop greater interest in learning" or "The use of ICT for teaching and learning distracts students from learning" in their opinion hold true (1 = does not hold true at all, 4 = fully holds true).

Uncertainty tolerance regarding the in-classroom use of ICT

We used four items based on the "Ungewißheitstoleranzskala" ("uncertainty tolerance scale", Dalbert 1999) adapted to ICT-assisted teaching as per Vennemann et al. (2021; see also Gerick and Killus 2024) and added four further items inspired by Dalbert (1999) which were also tailored to the context of teaching with ICT to measure participants' uncertainty tolerance regarding the in-classroom use of ICT (see also Hülshoff et al., 2025). The adapted instrument thus consists of eight items ($a = .69$). Participants were asked to indicate to what extent statements such as "I feel uncomfortable when lessons with ICT do not work as planned" or "When I try something with ICT, the pedagogical idea is more important to me than the concern about possible problems" hold true for them and their reference subject regarding their school practical experience so far (1 = does not hold true at all, 4 = fully holds true). Negatively keyed items were inverted before data analysis so that high values represent a high degree of domain-specific uncertainty tolerance.

3.3 Analyses and Assumptions

After descriptive data analyses, we conducted two-step cluster analyses, following similar approaches within the investigated field of study by, for example, Hülshoff and Jucks (2024), Jin and Schmidt-Crawford (2022) and Pozas et al. (2024) (RQ 1). Cluster analyses were (alternately) based on both, the Log-likelihood distance measure and Euclidean distance measure. Loosely inspired by the approach by Drossel and Eickelmann (2017), we compared two-, three-, four- and five-group-solutions to one another. Additionally, we conducted further cluster analyses without a pre-specified number of expected cluster (based on both (alternately), the Bayesian Information Criterion (BIC) and the Aikake Information Criterion (AIC); maximum of possible clusters: five). The cluster analyses included all variables concerning perceived availability of ICT-related LO during teacher education as well as the self-reported use of and satisfaction with ICT-related LO during teacher education.

All included variables were interpreted on a (quasi-)continuous level for these analyses. For many variables or cases, normality and independence assumptions were not met. However, the two-step cluster analysis is considered robust with regard to such violations of assumptions (Wentura & Pospeschill, 2015). We tested the final cluster-solution multiple times and varied the order in which variables were included in order to rule out sequence effects (see also Hülshoff & Jucks, 2024). We then conducted *t*-tests for independent samples to check for mean differences between clusters (RQ 1 and RQ 2). We used two-tailed *t*-tests for exploratory analyses and one-tailed *t*-tests when testing directed hypotheses. We left natural outliers that were spotted through visual box-plot interpretation in the sample because of the limited value range (see also Hülshoff & Jucks, 2024). According to findings from Shapiro-Wilk tests, normal distribution could not be assumed in all cases. However, the *t*-test for independent samples is considered robust with regard to violations of the normality assumption (Rasch & Guiard, 2004). Where homoscedasticity was not given according to results from Levene's test, we interpreted the Welch output, which has shown to be robust in cases of variance heterogeneity (Rasch et al., 2011). We examined bivariate correlations (Pearson's *r*; one-tailed) between participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT for the total sample as well as separately for the identified clusters. Linearity could be assumed in all cases based on visual scatterplots. Natural outliers spotted through visual box-plot interpretation again remained within the sample due to the limited value range. According to findings from Shapiro-Wilk tests, normality could be assumed for these correlation analyses. These assumption tests only refer to the correlation analyses based on the total sample. Finally, we used an online tool (Hemmerich, 2017) for inferential statistical analyses to compare correlation coefficients in the respective clusters systematically. All other statistical analyses were carried out with SPSS (Version 29; IBM, 2021). Analyses were based on listwise or pairwise deletion.

4. Results

4.1 Descriptive Results

Perceived ICT-related LO

Regarding perceived availability, participants in the sample of the present study on average reported the highest value for school practical LO ($M = 2.95$, $SD = 0.88$) and the lowest values for academic LO (academic LO – perceived availability I/learning: $M = 1.89$, $SD = 0.55$; academic LO – perceived availability II/guidance: $M = 1.74$, $SD = 0.50$) (Table 1). The highest use of available ICT-related LO, however, was reported within the realm of everyday life LO (everyday life LO – self-reported use I/use of ICT for social communication*:* $M = 3.08$, $SD = 0.47$). Also, the self-reported

use of academic LO ($M = 2.66$, $SD = 0.71$) was higher than the self-reported use of school practical ICT-related LO in the sense of the "use of ICT for teaching practices in class" (school practical LO – self-reported use I; $M = 2.04$, $SD = 0.66$) and of "collaboration between teachers using ICT" (school practical LO – self-reported use II; $M = 2.34$, $SD = 0.79$). Reported satisfaction was on average the highest for everyday life ICT-related LO ($M = 2.73$, $SD = 0.76$) and the lowest for academic ICT-related LO ($M = 1.98$, $SD = 0.80$).

Table 1: *Perceived ICT-related LO in the total sample and depending on cluster allocation (results from two-tailed t-tests for independent samples).*

	M (SD)						
	Total sample	Cluster 1	Cluster 2	*df*	*t/ Welch*	*p*	*d*
Academic LO							
Perceived availability I	1.89 (0.55)	2.02 (0.55)	1.64 (0.42)	125	**3.96**	**<.001**	**0.73**
Perceived availability II	1.74 (0.50)	1.85 (0.50)	1.54 (0.41)	125	**3.48**	**<.001**	**0.64**
Self-reported use	2.66 (0.71)	2.60 (0.68)	2.70 (0.73)	125	-0.70	.48	-0.13
Satisfaction	1.98 (0.80)	2.22 (0.79)	1.52 (0.62)	125	**5.16**	**<.001**	**0.95**
School practical LO							
Perceived availability	2.95 (0.88)	3.36 (0.68)	2.24 (0.74)	125	**8.68**	**<.001**	**1.60**
Self-reported use I	2.04 (0.66)	2.29 (0.64)	1.58 (0.38)	124,738	**7.80**	**<.001**	**1.26**
Self-reported use II	2.34 (0.79)	2.66 (0.76)	1.78 (0.48)	123,546	**7.99**	**<.001**	**1.31**
Satisfaction	2.26 (0.87)	2.62 (0.77)	1.59 (0.62)	125	**7.78**	**<.001**	**1.44**
Everyday life LO							
Perceived availability	2.78 (0.83)	2.86 (0.85)	2.65 (0.74)	125	1.42	.16	0.26
Self-reported use I	3.08 (0.47)	3.12 (0.46)	3.03 (0.50)	125	1.01	.31	0.19
Self-reported use II	2.34 (0.69)	2.45 (0.69)	2.19 (0.66)	125	**2.13**	**.04**	**0.39**
Satisfaction	2.73 (0.76)	3.02 (0.59)	2.17 (0.74)	77,816	**6.68**	**<.001**	**1.31**

Note. Significant results in bold.

Perceptions of positive and negative outcomes of the use of ICT for teaching and learning and uncertainty tolerance regarding the in-classroom use of ICT

The participants seemed by majority rather optimistic about the use of ICT for teaching and learning as the mean for "perceived positive outcomes of the use of ICT for teaching and learning" was above the scale center ($M = 2.87$, $SD = 0.46$), while the mean for "perceived negative outcomes of the use of ICT for teaching

and learning" was below the scale center ($M = 2.34$, $SD = 0.52$) (Table 2). Participants' uncertainty tolerance regarding the in-classroom use of ICT was rather low ($M = 2.26$, $SD = 0.44$).

Table 2: *Participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and uncertainty tolerance regarding the in-classroom use of ICT in the total sample and depending on cluster allocation (results from one-tailed t-tests for independent samples).*

	M (SD)						
	Total sample	Cluster 1	Cluster 2	*df*	*t/ Welch*	*p*	*d*
Perceived positive outcomes	2.87 (0.46)	2.89 (0.47)	2.85 (0.47)	125	0.47	0.32	0.09
Perceived negative outcomes	2.34 (0.52)	2.37 (0.51)	2.30 (0.54)	125	0.71	0.24	0.13
Uncertainty tolerance	2.26 (0.44)	2.29 (0.49)	2.24 (0.32)	122,732	0.71	0.24	0.12

4.2 Identified Clusters and Differences Between Clusters Regarding Perceived ICT-related LO (RQ 1)

Cluster analyses without a pre-specified number of expected clusters led to two-cluster-solutions (BIC/AIC) when the log-likelihood measure was used and to one-cluster-solutions when the Euclidean distance measure was used (BIC/AIC). However, for one-cluster-solutions, the ratio of smallest to largest cluster, by definition is 1 and the silhouette measure for cohesion and separation cannot be calculated. Results from the cluster analyses comparing two-, three-, four- and five-group-solutions are presented in Table 3. The ratio of smallest to largest cluster should be under 2.00 (Marques et al., 2021), which only applied to the two-cluster- and the three-cluster-solution from analyses based on the log-likelihood distance measure (Table 3). The silhouette measure for cohesion and separation indicated a medium cluster quality (> 0.1 and < 0.5) for both of these solutions but was higher for the two-cluster-solution (0.3).

Overall, the two-cluster-solution from the analysis based on the log-likelihood distance measure therefore showed the best fit. Results for this solution did not change when the order in which variables were included was changed. The smaller cluster comprised 47 participants (36.2%). The larger cluster comprised 83 participants (63.8%). The ratio smallest-to-largest-cluster was 1.77 for this solution (Table 3).

Table 3: *Results from two-step cluster analyses.*

Distance measure	Input	Number of clusters	Size of smallest cluster	Size of largest cluster	Silhouette measure for cohesion and separation	Ratio smallest/ largest cluster
Log-likelihood	12	2	47 (36.2%)	83 (63.8%)	0.3	1.77
Euclidean	12	2	2 (1.5%)	128 (98.5%)	0.5	64.0
Log-likelihood	12	3	36 (27.7%)	48 (36.9%)	0.2	1.33
Euclidean	12	3	2 (1.5%)	126 (96.9%)	0.3	63.0
Log-likelihood	12	4	13 (10.0%)	46 (35.4%)	0.2	3.54
Euclidean	12	4	2 (1.5%)	123 (94.6%)	0.2	61.50
Log-likelihood	12	5	11 (8.5%)	39 (30.0%)	0.2	3.55
Euclidean	12	5	2 (1.5%)	120 (92.3%)	0.2	60.0

Rounded to the first decimal place, participants' perceptions of the availability of ICT-related LO during teacher education, their self-reported use of ICT-related LO during teacher education and their satisfaction with ICT-related LO during teacher education differed statistically relevantly ($|d| \geq 0.20$) between clusters regarding eleven of the twelve used indicators Table 1). However, only nine of these differences were significant (Table 1). Participants in cluster 1 on average reported higher values for all indicators except for the self-reported use of academic ICT-related LO. Effect sizes for statistically significant group differences ranged from small ($0.20 \leq |d| < 0.50$) to high ($|d| \geq 0.80$). The smallest significant difference between clusters was found for the self-reported use of ICT-related LO in everyday life in the domain of "ICT as a topic of social interaction" (everyday life LO – self-reported use II) ($d = 0.39$). The largest significant difference was found for participants' perceptions of the availability of school practical ICT-related LO ($d = 1.60$).

4.3 Perceptions of Positive and Negative Outcomes of the Use of ICT for Teaching and Learning and Uncertainty Tolerance Regarding the In-classroom Use of ICT Depending Cluster Allocation (RQ 2)

Unexpectedly, neither participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning nor their uncertainty tolerance regarding the in-classroom use of ICT varied significantly depending on cluster allocation (Table 2).

4.4 Associations Between Perceptions of Positive and Negative Outcomes of the Use of ICT for Teaching and Learning and Uncertainty Tolerance Regarding the In-classroom Use of ICT (RQ 3)

As expected, there was a positive correlation between participants' perception of positive outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the classroom use of ICT ($r = .32$, $p < .001$) and significant negative correlations between participants' perceptions of negative outcomes of the use of ICT for teaching and learning and their perceptions of positive outcomes ($r = .-38$, $p < .001$) and their uncertainty tolerance ($r = -.20$, $p < .05$) in the total sample (Table 4). According to Cohen (1988), these first two correlations classify as moderate and the latter as small. In cluster 1, all these correlations were significant, too (Table 4). However, there was a stronger negative association between participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning ($r = -.55$, $p < .001$). In cluster 2, by contrast, none of these constructs were significantly associated with one another. Inferential statistical tests comparing the correlation coefficients from cluster 1 and cluster 2 identified significant differences regarding the correlations between perceived positive and negative outcomes of the use of ICT for teaching and learning ($z = -2.76$, $p < .01$) and between perceived nega-

Table 4: *Correlations (Pearson's r; one-tailed analyses) between participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT in the total sample and depending on cluster allocation.*

	Perceived positive outcomes	Perceived negative outcomes	Uncertainty tolerance
Total sample			
Perceived positive outcomes	1		
Perceived negative outcomes	-.38***	1	
Uncertainty tolerance	.32***	-.20*	1
Cluster 1			
Perceived positive outcomes	1		
Perceived negative outcomes	-.55***	1	
Uncertainty tolerance	.36***	-.32**	1
Cluster 2			
Perceived positive outcomes	1		
Perceived negative outcomes	-.10	1	
Uncertainty tolerance	.23	.05	1

Note. *$p < .05$. **$p < .01$. ***$p < .001$. Comparison of the correlation between perceived positive and negative outcomes of the use of ICT for teaching and learning in cluster 1 and cluster 2: $z = -2.76$, p (two-tailed) $< .01$. Comparison of the correlation between perceived positive outcomes of the use of ICT for teaching and learning and uncertainty tolerance in cluster 1 and cluster 2: $z = 0.75$, p (one-tailed) $= .77$. Comparison between perceived negative outcomes of the use of ICT for teaching and learning and uncertainty tolerance in cluster 1 and cluster 2: $z = -2.01$, p (one-tailed) $= .02$.

tive outcomes of the use of ICT for teaching and learning and uncertainty tolerance regarding the in-classroom use of ICT ($z = -2.01$, $p = .02$) but not for the correlation between perceived positive outcomes of the use of ICT for teaching and learning and uncertainty tolerance regarding the in-classroom use of ICT ($z = 0.75$, $p = .77$).

5. Discussion and Conclusions

5.1 Key Results and Possible Outline for Future Research

Descriptive findings of the present study showed how pre-service teachers in the underlying sample perceived, used and rated ICT-related LO – as perceived – during their teacher education up to the point of data collection. Overall, these results showed that the participants perceived a higher degree of available ICT-related LO in the school practical and everyday life realm than at university. Accordingly, reported satisfaction with academic ICT-related LO was on average lower than satisfaction with school practical and everyday life LO. However, the self-reported use of available academic ICT-related LO, where it was up to the participants, was rather high. On top of that, the descriptive findings showed that the participants were overall rather optimistic about possible outcomes of the use of ICT for teaching and learning while at the same time reporting a rather low degree of uncertainty tolerance regarding the classroom use of ICT.

The results from two-step cluster analyses indicated the best fit for a two-group-solution. Rounded to the first decimal place, values differed statistically relevantly for 11 of 12 indicators for ICT-related LO. Nine of these group differences were significant. Effect sizes for significant group differences ranged from small to ($0.20 \leq |d| < 0.50$) to high ($|d| \geq 0.80$). While the smallest significant difference ($d = 0.39$) based on cluster allocation was found for the self-reported use of ICT-related LO in everyday life (domain "ICT as a topic of social interaction"/everyday life LO – self-reported use II), the largest difference was identified regarding participants' perceptions of the availability of school practical ICT-related LO ($d = 1.60$). For most indicators, participants in cluster 1 reported on average higher values than participants in cluster 2. However, participants in cluster 2 reported on average higher values regarding self-reported use of academic ICT-related LO. To a certain degree, the findings resemble results from prior research that also identified good fits for two-group-solutions in samples of in-service teacher (Drossel & Eickelmann, 2017) or pre-service teachers (Jin & Schmidt-Crawford, 2022; Pozas et al., 2024) with groups that, overall, appeared diametrically opposed to another. However, it should be noted that cluster analyses from our study based on the Euclidean distance measure without a pre-specified number of expected clusters led to one-cluster-solutions, while for a three-cluster-solution based on the log-likelihood distance measure also a moderate fit was identified, which requires more in-depth examination (which might also adopt latent class analysis (LCA) approaches; see, for example, Drossel & Eickelmann, 2017) in future research.

Unexpectedly, the results did not indicate significant variance in participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning depending on their perceived ICT-related learning experience. To some degree, the findings in this regard align with results from previous research (Backfisch et al., 2024; Lachner et al., 2021; Valtonen et al., 2015). A reason for this might be that pre-service teachers' profession-related attitudes often tend to be rather stable (Guse et al., 2023; Rach, 2023). Also contradictory to our hypotheses, participants' uncertainty tolerance regarding the in-classroom use of ICT did not vary significantly depending on cluster allocation. These findings partly align with findings from a study by Hülshoff et al. (2025). This might be an indicator that even *domain-specific* uncertainty tolerance comprises a good amount of rather stable trait components. However, further in-depth investigation of this in future research seems worthwhile.

As expected, a significant positive correlation between pre-service teachers' perceptions of positive outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT as well as significant negative correlations between perceptions of negative outcomes of the use of ICT for teaching and learning and positive outcomes and uncertainty tolerance regarding the in-classroom use of ICT could be observed in the total sample as well as within cluster 1. These results align with findings from previous research (Hülshoff et al., 2025; Fraillon et al., 2019; Hülshoff & Jucks, 2024; Gerick & Killus, 2024). In the context of the ICILS 2018, for example, the correlation between in-service teachers' perceptions of positive and negative outcomes of the use of ICT for teaching within participating countries was on average $r = -.36$ (Fraillon et al., 2019). Hülshoff and Jucks (2024) identified a similar correlation between pre-service teachers' perceptions of the utility of ICT for teaching and assumed costs that might come with using ICT for teaching ($r = -.32$). The effect found in the total sample of our study for the correlation between participants' perceptions of positive and negative outcomes of the use of ICT for teaching and learning ($r = -.38$) resembles these prior findings. However, such associations were not found in cluster 2. Therefore, the evidence supports the assumption that perceived ICT-related LO may have an impact on associations between pre-service teachers' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT. However, this differs from the kind of variance we expected as the evidence does not suggest that ICT-related learning experiences that are perceived as particularly intense or positive weaken the interrelatedness between said variables but rather implies the opposite. Further investigation in future research is needed here, too.

5.2 Limitations and Further Possible Directions for Future Research

Regarding construct validity, it needs to be taken into account that the results of the present study solely rely on participants' (retrospective) self-reports and personal evaluations which are highly subjective and rather broad as well as likely to be prone to bias due to memory effect and social desirability (King & Bruner, 2000; Krosnick, 1991; Skowronski et al., 1991; Van Vaerenbergh & Thomas, 2013) and therefore need to be interpreted accordingly. It might be helpful for future research to also consider more objective measures of LO (see also Jentsch et al., 2021). However, the particular importance of subjectively perceived LO (Tachtsoglou & König, 2017) needs to be acknowledged, too. Also, the interpretation of at least some of the used measures on a (quasi-)continuous level needs to be critically reflected when interpreting the results of the present study (see also Carifio & Perla, 2007). With regard to internal validity, it needs to be noted that the present study does not allow conclusions regarding directions of possibly underlying causal relations due to the correlational research design. *Reciprocal* associations between self-reported use of perceived ICT-related LO and pre-service teachers' perceptions of positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT, for example, seem plausible in many cases. Therefore, more experimental research on possible effects of ICT-related LO in teacher education on prospective teachers' perspectives on ICT-assisted teaching is needed in future research. Especially since conducted analyses could not be controlled for potentially relevant site-specific framework conditions and comprise a broad range of different reference subjects, matters of external validity need to be addressed, too. Due to the underlying *convenience sample*, transferability of the results to other contexts (for example, other subjects, other universities, other countries and educational systems) cannot per se be assumed, which marks one conceivable starting point for possible follow-up research. It also needs to be stated that the results are not representative in any regard due to the way of sample recruitment and selection effects cannot be ruled out. Against this backdrop, it is important to emphasize that over-generalizing or too static interpretations of the clusters identified in the present research need to be avoided. Instead, a constructive and critical reflection of these clusters and the value of allocating pre-service teachers to such groups as well as more in-depth investigation (e. g., of potential clusters in other samples) in future research appear as an appropriate and fruitful avenue.

5.3 Possible Implications for the Professional Development of Pre-service Teachers

From our point of view, it is important to note for teacher educators that variance in both, *actual* ICT-related LO during teacher education as well as in pre-service teachers' *perceptions* of such LO may occur. The findings of the present study sug-

gest that actively promoting pre-service teachers' beliefs about positive and negative outcomes of the use of ICT for teaching and learning and their uncertainty tolerance regarding the in-classroom use of ICT during teacher education is ambitious. Also, it should be noted that, based on the present findings, there is a certain likelihood that, in some contexts, the (strengthening) impact of positive views on ICT-assisted teaching on pre-service teachers' uncertainty tolerance regarding the in-classroom use of ICT might be slightly stronger than the (weakening) effect of negative views on ICT-assisted teaching, although this is solely based on cross-sectional, correlational evidence. The findings of the study also raise the question of how to address learners who perceive a low amount of available ICT-related LO during teacher education and express little satisfaction with such LO. Against this backdrop, further research on how to design LO that better suit pre-service teachers' individual resources and needs (for example, based on questionnaires measuring pre-service teachers' perceived needs regarding their qualification for ICT-assisted teaching, see, for example, Henning-Kahmann & Hellmann, 2025) seems worthwhile.

Promoting innovative spirit and willingness to participate regarding the digitization of school education have been described as relevant and legitimate tasks (KMK, 2021). There are many didactical and methodological potentials that come with ICT-assisted teaching (for example, regarding adaptive teaching and learning or assessment) and pre-service teachers need to be able to recognize and use such potentials (KMK, 2016/2017). However, there are also challenges and risks associated with digitization (KMK, 2016/2017) and uncertainty tolerance (in general and domain-specific) may also have some protective functions (Hülshoff et al., 2025). Key to and central goal of ICT-assisted teaching is a *sensible* and *appropriate* integration of ICT into teaching and learning processes, classrooms and school life (KMK, 2016/2017). The normative foundations of teaching and learning processes always require critical reflection and discussion (KMK, 2004/2022). Pre-service teachers should be supported in forming and developing their own, responsible and well-founded opinions about and approaches toward ICT-assisted teaching (KMK, 2004/2022; 2016/2017).

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Appendix

Table 5: *ICT-related LO: perceived availability, self-reported use and satisfaction (correlation matrix; results from two-tailed correlation analyses).*

	1	2	3	4	5	6	7	8	9	10	11	12
1	1											
2	.74***	1										
3	.03	-.02	1									
4	.47***	.49***	-.01	1								
5	.11	.08	-.10	.10	1							
6	.20*	.17	-.01	.18*	.52***	1						
7	.02	.13	.07	.12	.52***	.60***	1					
8	.18*	.20*	-.05	.41***	.41***	.56***	.47***	1				
9	.06	-.09	.13	.05	.01	.13	.11	.18*	1			
10	.03	-.03	.01	-.07	.10	-.05	-.06	-.14	.07	1		
11	.09	.14	.01	.04	.03	.15	.10	-.07	.26**	.34***	1	
12	.27**	.22*	-.07	.37***	.30***	.23**	.21*	.41***	.20*	.02	.06	1

Note. 1 = Academic LO – perceived availability I. 2 = Academic LO – perceived availability II. 3 = Academic LO – self-reported use. 4 = Academic LO – satisfaction. 5 = School practical LO – perceived availability. 6 = School practical LO – self-reported use I. 7 = School practical LO – self-reported use II. 8 = School practical LO – satisfaction. 9 = Everyday life LO – perceived availability. 10 = Everyday life LO – self-reported use I. 11 = Everyday life – self-reported use II. 12 = Everyday life LO – satisfaction. *$p < .05$. **$p < .01$. ***$p < .001$.