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Teachers' emphasis on developing students' digital information and communication skills (TEDDICS): A new construct in 21st century education

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ABSTRACT

The main aim of this study is to validate an instrument to measure teachers' emphasis on the development of students' digital information and communication skills (TEDDICS), a construct that describes a qualitative aspect of ICT use beyond mere frequency reports. TEDDICS was conceptualized by focusing on digital skills such as accessing, evaluating, and sharing and communicating digital information. We validated TEDDICS with respect to its factorial structure, relations to further teacher-related variables (e.g., ICT self-efficacy), background characteristics (age and gender), and main subject differences. The Norwegian International Computer and Information Literacy Study (ICILS) 2013 teacher sample ($N = 1072$) showed that TEDDICS: (a) comprises three factors which can be identified by exploratory structural equation modeling (ESEM); (b) is positively related to ICT self-efficacy, the frequency of ICT use, and perceived usefulness of ICT; (c) differs across main subjects but not across gender groups. In addressing our research aims, we show that ESEM represents TEDDICS more appropriately than confirmatory factor analysis. Our results provide strong evidence on the construct validity and point out to the importance of looking at the degree to which teachers emphasize digital skills in classrooms beyond the frequency of using ICT.

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1. Introduction

Students' digital information and communication skills have gained substantial attention during the last decade and are regarded as important skills in the 21st century (Griffin, Care, & McGaw, 2012). These skills refer to several aspects related to knowledge, beliefs, attitudes, and values concerning information and communication technology (ICT), covering a variety of contexts and new technologies (Ferrari, 2013). New technologies have made searching for and accessing information easy and available for everybody. However, since the Internet offers opportunities for everyone to publish independently of the quality of the information dispatched, it is essential for students to develop skills to deal with digital information (Ferrari, 2013). In a recent study, Strømso and Bråten (2014) argued that undergraduates need more training in sourcing and evaluating digital

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information. These skills are of particular importance, because they are beyond mere information search. In fact, evaluating information and using it in order to solve tasks, present the results, and collaborate with others are regarded as crucial competencies students are supposed to acquire (Griffin, Care, & McGraw, 2012; Pellegrino & Hilton, 2012). Moreover, these skills are crucial for adults in order to fulfill the working demands in the 21st century (OECD, 2013).

In order to provide opportunities to acquire these skills, teachers and schools are expected to integrate ICT into their classroom practice (Schibeci et al., 2008; Tondeur, van Keer, van Braak, & Valcke, 2008). Consequently, research has focused on the factors determining especially teachers' ICT integration (Donnelly, McGarr, & O'Reilly, 2011). Among these factors, self-efficacy, perceived usefulness, perceived ease of use, teaching beliefs, ICT anxiety, and general attitudes towards computers have been identified as relevant determinants (e.g., Compeau, Higgins, & Huff, 1999; Igarria, Parasuraman, & Baroudi, 1996; Mac Callum, Jeffrey, & Kinshuk, 2014; Sang, Valcke, Braak, & Tondeur, 2010; Teo, 2011; Tondeur, Valcke, & van Braak, 2008). But these factors of ICT integration mainly refer to teachers' perceptions of their ICT skills and the usefulness of integrating ICT in teaching and learning. Although there is a trend of shifting research beyond these perceptions (e.g., 'technological pedagogical content knowledge'; Voogt, Fisser, Roblin, Tondeur, & van Braak, 2012), it is surprising that a detailed view on how teachers actually emphasize the development of students' digital information and communication skills in classrooms is lacking.

Teachers' emphasis on developing students' digital information and communication skills (TEDDICS) differs from the factors mentioned earlier, because it does not refer to personal beliefs or the use of ICT regarding its quantity or technology specificity (e.g., Which kinds of ICT tools and software are used?). Instead, TEDDICS is a goal-oriented construct that combines the use of ICT, teaching practice, curricular demands, and beliefs about which ICT skills are important. In fact, following Schmid, Bernard et al.'s (2014) plea for shifting research "toward a more fine-grained analysis of identified instructional factors" (p. 286), studying TEDDICS provides valuable information on the link between students' digital skills and teachers' classroom practice.

Against this background, the present study is aimed at investigating TEDDICS, a newly studied construct, with respect to its validity. On the basis of the Norwegian International Computer and Information Literacy Study (ICILS) 2013 sample, we approach (a) the factorial structure; (b) the relations to other constructs; and (c) differences across gender and main subject groups by using exploratory structural equation modeling. We sought to gather evidence on different aspects of construct validity (AERA, APA, & NCME, 2014; Messick, 1995).

2. Theoretical framework

2.1. Students' digital information and communication skills

Students' digital competence has been described in a number of frameworks, comprising many dimensions and aspects (Ferrari, 2012; Voogt et al., 2012). For instance, Ferrari (2013) proposes five different areas for which a number of essential competences are described. One of these areas is concerned with the aspects of dealing with digital information, which are considered important skills in the 21st century (Griffin et al., 2012; Strømsø & Bråten, 2014). Regarding this competence area, most of the frameworks distinguish between search, evaluation, and communication processes (Calvani, Cartelli, Fini, & Ranieri, 2009; Ferrari, 2013; Fraillon, Schulz, & Ainley, 2013; International ICT Literacy Panel, 2007). In addition, research on the operationalization of *digital information skills* tends to keep this distinction and indicates that students lack these skills and experience problems related to information retrieval and processing skills (e.g., defining proper search queries, evaluating information, presenting and communicating information in non-structured digital environments; Aesaert, van Nijlen, Vanderlinde, & van Braak, 2014; Calvani, Fini, Ranieri, & Picci, 2012; Kuiper, Volman, & Terwel, 2005). In sum, distinguishing between the different skills involved in mastering digital information (i.e., accessing, evaluating, sharing and communicating; e.g., Ferrari, 2013) may provide a conceptual framework for describing teachers' emphasis on the development of these skills in their classrooms.

2.2. Teachers' emphasis on developing students' digital information and communication skills (TEDDICS)

In light of the considerations on the multiple dimensions of students' digital information and communication skills, the degree to which teachers emphasize fostering these skills in classrooms can be regarded as a multidimensional construct, describing a qualitative rather than a quantitative facet of ICT use (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014). In fact, instead of looking at the frequency of using ICT, studying TEDDICS provides detailed information on the synergy between curricular demands and teachers' beliefs about the importance of digital skills, further linking it to the development of students' competence in this area (Fraillon et al., 2013).

Considering evidence drawn from empirical studies on the multidimensionality of digital information skills, we seize the factorial structure of the TEDDICS construct consisting of three factors: *Access digital information*, *Evaluate digital information*, and *Share and communicate digital information*. Although these three factors are conceptually distinct, they may overlap because they refer to the same overall concept concerning digital information. Additionally, they may represent a sequence of processes: For instance, when sharing information students need to filter it beforehand. Further, the evaluation process follows the search for digital information. Hence, the three factors appear interwoven, leading to a construct overlap that

could affect the characteristics of the corresponding measurement models (e.g., in form of item cross-loadings; Marsh et al., 2009).

In order to draw adequate conclusions from information on TEDDICS, sufficient evidence on construct validity, that is, the degree to which empirical data and substantive theory support the interpretation based on assessment outcomes (Messick, 1995), must be gathered. One way to establish construct validity is to study the internal structure of the construct (internal validity). As a common practice, the relations to external variables are also used (external validity) for validation purposes (e.g., Huggins, Ritzhaupt, & Dawson, 2014). Since the TEDDICS construct has not yet been validated externally, we review existing research on potential external correlates in the following section.

2.3. Relations to Teacher beliefs: perceived usefulness and self-efficacy

Research in the context of teachers' intentions to use ICT in classrooms has focused on teacher beliefs as potential determinants. For instance, *perceived usefulness of ICT* is related to the degree to which a person believes that using ICT would enhance his or her performance (Davis, 1989). A wide range of studies on teachers acceptance and integration of ICT suggested that perceived usefulness is a critical indicator for predicting their ICT use in the classroom (Chen, 2010; Chien, Wu, & Hsu, 2014; Ertmer, 2005; Scherer, Siddiq, & Teo, 2015; Teo, 2011). Since teachers' perceived usefulness refers to the *beliefs in ICT* as tools for teaching and learning, researchers have also studied teachers' *beliefs in their own skills*, that is, their *self-efficacy* of using ICT as another source of beliefs (Chien et al., 2014; Igbaria et al., 1996; Kreijns, Vermeulen, Kirschner, van Buuren, & Van Acker, 2013). In a review of factors affecting teachers' integration of ICT, Mumtaz (2000) reported self-efficacy as a crucial determinant, stating that, in order to use ICT in the classroom, teachers need to be confident about their abilities of using ICT effectively in instructional practice.

Taken together, since research indicates that teacher beliefs in their digital skills and the usefulness of ICT for teaching and learning can be regarded as important determinants of teachers' intention to use and the frequency of ICT use, they may also correlate with TEDDICS as a qualitative aspect of ICT use.

2.4. Differences across age, gender, and main subjects

In the context of ICT integration and technology acceptance, research has also identified age, gender, and main subjects of teachers as potential sources of variation. In this section, we summarize some of the existing research findings.

Teachers' age. Teachers' age was incorporated as a moderating variable in the technology acceptance model and extensions of it (e.g., Venkatesh, Morris, Davis, & Davis, 2003). In this context, researchers' main goal was to study whether the associations between constructs such as perceived usefulness and the intention to use ICT vary across age groups. For instance, Venkatesh et al. (2003) found that technology use was more strongly influenced by attitudes of younger adults. In contrast, the perceptions of the expected effort in using ICT became more important with increasing age. Research has also revealed that age negatively affects the use of ICT, meaning that older teachers are less likely to use ICT in classrooms (Morris & Venkatesh, 2000; Vanderlinde, Aesaert, & van Braak, 2014; Venkatesh et al., 2003). O'Bannon and Thomas' (2014) and Scherer et al.'s (2015) studies supported this finding by identifying the negative relation between teachers' age and their integration of and attitudes towards ICT.

Gender differences. Teo's (2014) study of teachers' technology acceptance indicated that male teachers scored higher than female teachers in the perceived ease of ICT use. Nevertheless, due to small effect sizes this result could not be interpreted as conclusive for studying the impact of gender on technology acceptance (Teo, 2014). Regarding other constructs such as ICT self-efficacy, perceived usefulness, attitudes, anxiety, and prospective ICT use, a number of studies did not find significant gender differences (e.g., Antonietti & Grigoriotti, 2006; Phelps, 2002; Sang et al., 2010). On the contrary, other studies reported significant gender effects for different teacher samples and cohorts (Oosterwegel, Littleton, & Light, 2004; Scherer & Siddiq, 2015; Shashaani, 1993; Sink, Sink, Stob, & Taniguchi, 2008; Volman & van Eck, 2001). The inconclusive findings on the gender differences in ICT-related constructs (Teo, 2008) warrant a deeper look into whether gender differences occur for the newly studied construct of TEDDICS.

Main subject differences. Teachers' use of ICT is mostly related to teaching and learning activities in specific subjects (Hennessy, Ruthven, & Brindley, 2005; Selwyn, 1999). Lave and Wenger (1991) pointed out that subject cultures are important contextual factors affecting the way teachers use and perceive ICT. In fact, Hennessy et al. (2005) found substantive differences between teachers in different subjects (Mathematics, English, and Science) related to use of ICT, the commitment to integrate ICT in subject teaching (school policy), and the expertise and confidence in using ICT. For instance, mathematics teachers reported the strongest feelings of pressure to use ICT, but the least reluctance to use it and most external restraints. Science teachers were more positive towards the educational benefits of using ICT, whereas English teachers reported less ICT use, more anxiety, and feelings of reluctance to use it. The largest variations were found between English teachers and teachers in mathematics and science (Hennessy et al., 2005). In a meta-analysis on the effects of technology use in post-secondary education, Schmid, Bernard, et al. (2014) reported contradicting results differentiating between Science, Technology, Engineering, and Mathematics (STEM) and non-STEM subjects with respect to teachers' levels of ICT integration. In particular, the results revealed that teachers in STEM subjects benefit more from the use of technology than non-STEM subject teachers. However, a number of studies included in the meta-analysis showed contrasting results. Again, teachers' use of ICT in a subject may vary according to their beliefs of its usefulness for this specific subject.

Coming back to the different TEDDICS factors that refer to students' skills of mastering digital information, we argue that the degree to which ICT is used to foster these skills depends on their emphasis within a subject. For instance, since science education has put a strong emphasis on inquiry-based learning and the use of models (e.g., Crawford, 2012; Taber, 2013), developing digital skills in science most often involves inquiry-based virtual environments (Donnelly et al., 2011; Scherer & Tiemann, 2012) and simulations for visualization purposes (Barrett, Stull, Hsu, & Hegarty, 2015) rather than tools to access, evaluate, share and communicate digital information. In consequence, the results of the studies presented corroborate the notion that subjects can be an important factor in determining teachers' use of ICT and may therefore lead to differences in TEDDICS.

2.5. The present study

Bringing the two lines of research on teachers' integration of ICT for teaching and learning and students' digital competence as being multidimensional together, the present study attempts to validate TEDDICS. Following Messick's (1995) conceptualization of validity, we gather evidence on construct validity from two sources: First, we study the factorial structure of TEDDICS, distinguishing between three factors of students' digital skills (accessing, evaluating, and sharing and communicating digital information). Since we proposed that these factors may not be strictly distinct, we hypothesize the existence of construct overlaps. Hence, our expectation is that a three-factor measurement model with item cross-loadings represents the structure of TEDDICS appropriately (internal validity). Second, addressing external validity, we investigate the relations of TEDDICS to further constructs that are closely related to teachers' technology acceptance and the frequency of ICT use (e.g., Fraillon et al., 2014). Finally, we test the invariance of the TEDDICS factor structure across gender and main subject groups in order to study the comparability of the measurement model and potential differences in factor means. This is critically important, because a comparable measure of TEDDICS is crucial for drawing valid inferences on group differences. Specifically, if measurement invariance is not met sufficiently, mean comparisons are compromised (Millsap, 2011). From a generalizability point of view, testing for measurement invariance provides an additional source of evidence for construct validity (Messick, 1995). From an individual differences point of view, differences may occur, as the frequency of using ICT may also vary across teachers (Hennessy et al., 2005; Oosterwegel et al., 2004).

Taken together, we address three research questions in the present study:

1. To what extent can the hypothesized structure of TEDDICS distinguishing between the three overlapping factors (accessing, evaluating, and sharing and communicating digital information) be confirmed?
2. To what extent is TEDDICS related to variables such as teachers' ICT self-efficacy, perceived usefulness of ICT, ICT use, and age?
3. Does TEDDICS provide a measure which is invariant over gender and main subjects, and to what extent do mean differences exist?

3. Method

3.1. Sample and procedure

The sample of the present study comprised $N = 1072$ Norwegian teachers, who participated in the International Computer and Information Literacy Study (ICILS) in 2013 (Fraillon et al., 2014). Teachers were randomly sampled from 132 secondary schools in different municipalities across Norway and the sampling was based on schools' composition, background, and socio-economic characteristics. Teachers' mean age was 44.5 years ($SD = 15.5$) and ranged between 24 and 72 years. In total, 64.2% were female. Teachers' main subjects were Humanities, Language and Arts (51.6%), Mathematics and Science (26.4%), and other subjects such as Physical education, Food and health, and Religion, philosophies of life and ethics (22.1%). The teacher questionnaire contained background information (e.g., age, gender, and main subjects), the TEDDICS scale, and scales on the frequency of teachers' ICT use, self-efficacy, and perceived usefulness.

Given the relatively large sample size and the moderate complexity of the models specified in the present study, we chose the 1%-level of significance (Noymer, 2008).

3.2. Measures

In the present study, we used measures on TEDDICS, the frequency of teachers' ICT use for teaching and learning, teachers' ICT self-efficacy, and perceived usefulness of ICT. These measures were obtained from teachers' self-reports, as administered in ICILS 2013. We estimated McDonald's ω as a measure of scale reliability (Yang & Green, 2011). Descriptive statistics of each of the measures are shown in Table 1.

Teachers' emphasis on the development of students' digital information and communication skills (TEDDICS). Since students' skills in accessing, evaluating, and sharing and communicating digital information are considered crucial factors of digital competence (Fraillon et al., 2013), we used a multidimensional measure of TEDDICS that directly referred to the three factors: Accessing digital information ($\omega = .79$, 3 items), Evaluating digital information ($\omega = .90$, 4 items), and Sharing and

Table 1
Descriptive statistics of the constructs under investigation.

Construct	N_{Items}	$M (SD)$	Range	ω
1. TEDDICS	12	1.66 (.65)	.0–3.0	.92
2. ICT use	11	.80 (.37)	.0–2.0	.84
3. ICT self-efficacy for teaching	4	1.85 (.28)	.3–2.0	.76
4. ICT perceived usefulness	5	1.96 (.40)	.6–3.0	.67

Note. N_{Items} = Number of items, ω = McDonald's ω (reliability). The means and standard deviations are normed by the number of items for each scale. $N = 1072$.

communicating digital information ($\omega = .80$, 5 items). Item wordings and detailed information on the descriptive statistics of items are presented in Table 2. Teachers were asked to rate the degree to which they emphasize the development of students' skills in their lessons ($0 = no\ emphasis$, $3 = strong\ emphasis$). The analyses did not show ceiling or floor effects. The scale's reliability was very good ($\omega = .92$).

Teachers' use of ICT for teaching and learning. Since the use of ICT in classrooms is multidimensional (Donnelly et al., 2011), we used the available items that represented two different facets: ICT use for teaching purposes such as student assessment, feedback, and the presentation of information (7 items; labeled as 'ICT use: Teaching'; e.g., *Assessing students' learning through tests, Reinforcing learning of skills through repetition of examples*), and ICT use for collaboration (4 items; labeled as 'ICT use: Collaboration'; e.g., *Enabling students to collaborate with other students*). Teachers were asked to report on the frequency of using ICT for these purposes ($0 = never$, $1 = sometimes$, $2 = often$). The scale showed a good reliability ($\omega = .84$).

Teachers' ICT self-efficacy for teaching. Teachers' ICT self-efficacy for teaching refers to their beliefs in their competencies of using ICT for teaching purposes (Lee & Lee, 2014). The construct was assessed by using four items (e.g., *Monitoring students' progress by means of ICT*), which teachers had to rate on a 3-point scale ranging from 0 (*I do not think I could do this*) to 2 (*I know how to do this*). The scale's reliability was acceptable ($\omega = .76$).

Teachers' perceived usefulness of ICT. As described in previous studies, teachers' perceived usefulness of ICT refers to the degree to which they believe that the use of ICT would increase their performance in teaching (e.g., Davis, 1989; Teo, 2011). We used 5 items to assess two different aspects of the construct: perceived usefulness of ICT for fostering collaboration (3 items; labeled as 'Perceived usefulness: Collaboration'; e.g., *ICT helps students learn to collaborate with other students*) and perceived usefulness of ICT for fostering students' skills of information processing (2 items; labeled as 'Perceived usefulness: Information processing'; e.g., *ICT helps students to consolidate and process information more effectively*). These aspects correspond to the factors of 'Accessing digital information' and 'Sharing and communicating digital information' in the TEDDICS scale. Teachers had to rate the items according to their agreement on a 4-point Likert scale ($0 = strongly\ disagree$, $3 = strongly\ agree$). The reliability of this scale was reasonable ($\omega = .67$), given the limited number of items.

3.3. Statistical analyses

In order to investigate the factorial structure of TEDDICS, we applied confirmatory factor analysis and exploratory structural equation modeling (Research Question 1). The relations of TEDDICS to further constructs were studied within a structural equation modeling framework (Research Question 2). We tested the measurement model of TEDDICS for invariance to ensure that it provides comparable measures and studied the differences across gender and main subjects (Research Question 3).

Exploratory structural equation modeling (ESEM). In many substantive applications, confirmatory factor analysis (CFA) is used to describe the factorial structure of constructs and to test for measurement invariance across pre-defined groups of persons (Marsh, Morin, Parker, & Kaur, 2014). This approach is, however, based on assumptions that may not reflect the nature of the construct. In particular, CFA assumes perfect item-factor links, that is, each item is assigned to only one factor, not allowing for cross-loadings (Fig. 1). However, in many applications, perfect item-factor links are not given, because items may induce the measurement of two or more aspects of a construct (e.g., Muthén & Asparouhov, 2012). Against this background, Marsh et al. (2009) developed a new type of factor-analytic model, which combines the features of CFA with exploratory factor analysis. This type is referred to as 'Exploratory Structural Equation Modeling'. ESEM is flexible enough to abandon the strict assumption of perfect item-factor links by accounting for cross-loadings (Fig. 1). Moreover, in ESEM it is possible to add correlated residuals, covariates, and multi-group structures to the measurement model (Marsh et al., 2009). This allows researchers to further study the construct with respect to its validity by investigating the relations to other constructs (Fig. 2) and the generalizability of the measurement model across groups. Another advantage of ESEM is that, in contrast to CFA, factor correlations are not overestimated (Marsh et al., 2014).

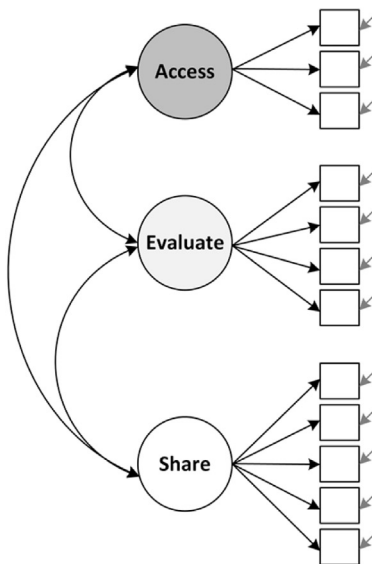
Specifically, regarding the estimation procedure, ESEM rotates the preliminary and freely estimated data structure by using, for instance, oblique rotation methods such as the target rotation, in which cross-loadings are set to approximately zero, reflecting the a-priori assumption that cross-loadings may exist but are close to zero (Asparouhov & Muthén, 2009; Marsh et al., 2009, 2014). In light of the advantages of using ESEM and since we assumed that the TEDDICS factors (i.e.,

Table 2

Item wordings and descriptive statistics of the 'teachers' emphasis on developing students' digital skills' (TEDDICS) scale.

Item wordings	Label	M	SD	Mdn	Skewness	Kurtosis	Range
Factor 1: accessing digital information							
Accessing digital information efficiently	Access1	1.93	.76	2.00	-.62	.39	0–3
Exploring a range of digital resources while searching for information	Access2	1.49	.88	2.00	-.17	-.72	0–3
Providing references for digital information sources	Access3	1.77	.87	2.00	-.47	-.36	0–3
Factor 2: evaluating digital information							
Evaluating the relevance of digital information	Evaluate1	1.82	.83	2.00	-.50	-.17	0–3
Evaluating the credibility of digital information	Evaluate2	1.87	.86	2.00	-.56	-.22	0–3
Validating the accuracy of digital information	Evaluate3	1.74	.86	2.00	-.41	-.40	0–3
Evaluating own strategies of digital information search	Evaluate4	1.40	.85	1.00	-.07	-.69	0–3
Factor 3: sharing and communicating digital information							
Displaying digital information for a given audience and a specific purpose	Share1	1.94	.87	2.00	-.73	.02	0–3
Sharing digital information with others	Share2	1.46	.85	2.00	-.13	-.65	0–3
Using computer software to make digital products (for presentations, documents, pictures, and diagrams)	Share3	1.97	.86	2.00	-.75	.11	0–3
Providing digital feedback on the work of others	Share4	.91	.88	1.00	.69	-.30	0–3
Understanding the consequences of making digital information available for everyone on the internet	Share5	1.70	1.00	2.00	-.29	-.97	0–3

Confirmatory factor-analytic model (CFA)



Exploratory structural equation model (ESEM)

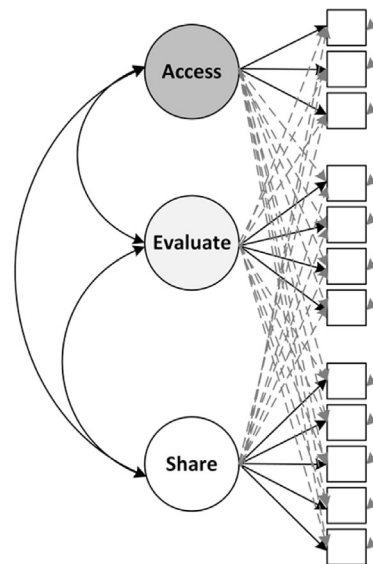


Fig. 1. Factor-analytic models describing the structure of TEDDICS. *Access* = Accessing digital information, *Evaluate* = Evaluating digital information, *Share* = Sharing and communicating digital information. Note. Dashed lines indicate item cross-loadings.

accessing, evaluating, and sharing and communicating digital information) show an overlap, we regard ESEM as a more appropriate representation of the factorial structure than CFA.

Invariance testing. We tested the factor model of TEDDICS for measurement invariance across the gender (G) and main subject groups (S) by means of multi-group structural equation modeling (Brown, 2013; Millsap, 2011). In this procedure, we established a sequence of models with increasing restrictions of the measurement model. Specifically, restrictions to equality across groups were imposed on the factor loadings (i.e., the links between items and factors), item intercepts (i.e., the item mean values), and the residual variances (i.e., the variance that is not explained by the latent variable).

First, we specified the least restrictive model, in which the factorial structure of the construct was freely estimated for each group. This model refers to 'configural invariance' and assumes the same number of factors and the same model specifications (i.e., the way how the latent variables are linked to the items) across groups (Model M1). If the assumptions of this model hold, the second step is to constrain the factor loadings to test for 'metric invariance' (Model M2). Evidence for metric invariance implies that the relations between latent variables can be compared. Third, in addition to the metric invariance model, we constrained the item intercepts. This model of 'scalar invariance' (Model M3) forms the prerequisite of comparing the means of latent variables. Finally, the most restrictive model, namely 'strict invariance' (Model M4), was estimated by constraining

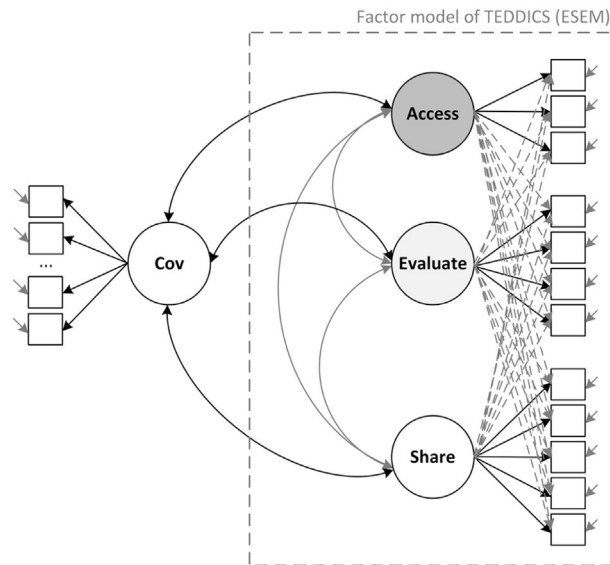


Fig. 2. Exploratory structural equation model describing the relations between TEDDICS and another construct (Covariate, *Cov*). *Access* = Accessing digital information, *Evaluate* = Evaluating digital information, *Share* = Sharing and communicating digital information. Note. Dashed lines indicate item cross-loadings.

the item residuals to test the assumption of equal reliabilities. If this model holds, the means of manifest variables (e.g., sum scores) can be compared across groups (Millsap, 2011).

Model fit. For evaluating the fit of the model and for comparing models with different specifications, we investigated so-called goodness-of-fit statistics. These statistics can provide an indication of misspecifications in a model that is designed to represent the assumptions on the data. The most commonly used fit statistics are (Marsh, Hau, & Grayson, 2005): the Satorra-Bentler corrected χ^2 value ($SB-\chi^2$), the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), the Tucker Lewis Index (TLI), and the Standardized Root Mean Square Residual (SRMR). These goodness-of-fit indices provide a comprehensive summary of the model's ability to reproduce the input covariance matrix (Brown, 2015, p. 96). For further details on how these indices are estimated, please refer to respective literature such as Marsh et al. (2005) and Kaplan (2009).

In the current study, we evaluated the model fit according to the guidelines for an acceptable model fit proposed by Marsh et al. (2005): $RMSEA \leq .08$, $CFI \geq .95$, $TLI \geq .95$, $SRMR \leq .10$. For the χ^2 values of the models, we used the Satorra-Bentler correction (Satorra & Bentler, 2010). In light of the large sample size, this statistic might show a significant value although the model fits the data. As a consequence, we did not base our decision for or against a model solely on this statistic.

To compare the multi-group models, we examined the changes in the CFI, TLI, and RMSEA. Differences of $\Delta CFI \geq -.010$, $\Delta TLI \geq -.010$, and $\Delta RMSEA \leq -.015$ between the configural (baseline) model and the more restrictive model indicate no substantial change in model fit (Cheung & Rensvold, 2002). On the basis of these model comparisons, we decided on the level of invariance. All analyses were employed in the statistical package *Mplus* 7.2 (Muthén & Muthén, 1998–2014).

Handling clustered and missing data. Due to the clustered structure of the teacher data (i.e., teachers as level-1 units and schools as level-2 units), we adjusted the standard errors of the model parameters. More precisely, we used the robust maximum likelihood estimator (MLR) and the TYPE = COMPLEX option in *Mplus*. Furthermore, differences in the probabilities of being sampled as a teacher were handled by using sampling weights (Asparouhov, 2005).

Among the teachers who took the questionnaire on the constructs under study, low proportions of missing values at the item level occurred (up to .5%). Since these missing values were not due to the design of the study, we assumed that they were 'missing at random' and applied the Full-Information-Maximum-Likelihood procedure to handle them (Enders, 2010).

4. Results

4.1. Factorial structure of TEDDICS

We addressed our first research question by using CFA and ESEM to validate the three factors of the TEDDICS scale: *Accessing digital information*, *Evaluating digital information*, and *Sharing and communicating digital information*. Whereas the underlying assumption of CFA is that each item belongs to only one factor, ESEM takes into account the potential overlap between factors (Fig. 1). For the CFA model, the fit indices indicated a poor fit (Table 3). Hence, we did not accept this model as a measurement model of the construct. In contrast, all cutoff-criteria for the fit indices were met for ESEM (Table 3). Moreover, ESEM significantly outperformed the CFA model ($\Delta RMSEA = -.025$, $\Delta CFI = +.061$, $\Delta TLI = +.062$) and was thus accepted.

The CFA model showed high factor loadings and correlations between the latent variables (Table 3). Since the ESEM approach takes into account the overlap between factors, the model resulted in lower factor correlations ($\rho = .53-.70$), as

Table 3

Standardized factor loadings, factor correlations, and model fit for the confirmatory factor-analytic (CFA) and exploratory structural equation model (ESEM).

Item	CFA			ESEM		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
<i>Factor 1: accessing digital information</i>						
Access1	.75 (.03)^a	–	–	.60 (.09)^a	.24 (.07) ^a	.03 (.06)
Access2	.77 (.02)^a	–	–	.28 (.10)^a	.18 (.08)	.41 (.05) ^a
Access3	.70 (.03)^a	–	–	.35 (.11)^a	.15 (.08)	.28 (.07) ^a
<i>Factor 2: evaluating digital information</i>						
Evaluate1	–	.83 (.02)^a	–	.43 (.06) ^a	.51 (.05)^a	.00 (.05)
Evaluate2	–	.90 (.02)^a	–	–.04 (.06)	1.05 (.10)^a	–.14 (.06)
Evaluate3	–	.72 (.03)^a	–	–.13 (.08)	.98 (.09)^a	.03 (.04)
Evaluate4	–	.89 (.02)^a	–	.06 (.07)	.30 (.06)^a	.54 (.04) ^a
<i>Factor 3: sharing and communicating digital information</i>						
Share1	–	–	.74 (.02)^a	.35 (.07) ^a	.21 (.07) ^a	.25 (.07)^a
Share2	–	–	.69 (.02)^a	–.02 (.05)	.20 (.05) ^a	.60 (.06)^a
Share3	–	–	.63 (.03)^a	.40 (.07) ^a	.01 (.05)	.31 (.08)^a
Share4	–	–	.59 (.03)^a	.01 (.06)	–.05 (.06)	.74 (.07)^a
Share5	–	–	.69 (.03)^a	.14 (.08)	.25 (.06) ^a	.38 (.07)^a
<i>Factor correlations</i>						
Factor 2	.88 (.02) ^a	–	–	.70 (.05) ^a	–	–
Factor 3	.91 (.03) ^a	.84 (.03) ^a	–	.53 (.06) ^a	.64 (.04) ^a	–
<i>Model fit indices</i>						
SB- χ^2 (df)	351.2 (51) ^a			118.5 (33) ^a		
CFI	.914			.975		
TLI	.888			.950		
RMSEA	.074			.049		
CI _{90-RMSEA}	[.067, .081]			[.040, .059]		
SRMR	.051			.022		

Note. Standard errors are shown in parentheses. CI_{90-RMSEA} = 90% confidence interval of the RMSEA, N = 1072.

Factor loadings in bold letters refer to the items that were originally assigned to the factors.

^a $p < .01$.

compared to CFA ($\rho = .84$ – $.91$). In the ESEM approach, the highest correlation was found between the factors of *Accessing digital information* and *Evaluating digital information*.

Factor loadings of the ESEM varied and some items had high cross-loadings between the three TEDDICS factors. In particular, three groups of items could be distinguished with respect to the cross-loadings: In the first group, items loaded on the factor they were originally assigned to and showed low cross-loadings. For instance, the item '*Providing digital feedback on the work of others*' (*Share4*) showed a high loading on the '*Sharing and communicating digital information*' factor ($\lambda_3 = .74$), but insignificant cross-loadings on the other factors ($\lambda_1 = .01$, $\lambda_2 = -.05$). In the second group, the highest loadings occurred on the factor the items were originally assigned to, but significant cross-loadings indicated a construct overlap. For instance, the item '*Accessing digital information efficiently*' (*Access1*) showed the highest loading on the factor of '*Accessing digital information*' ($\lambda_1 = .60$) and a significant cross-loading on the factor of '*Evaluating digital information*' ($\lambda_2 = .24$), indicating that the item-factor link is not perfect. Finally, the third group consisted of items with the highest loadings on a factor they were not originally assigned to (i.e., the cross-loadings are even higher than the hypothesized main loading). For instance, the item '*Evaluating own strategies of information search*' (*Evaluate4*) showed the highest loading on '*Sharing and communicating digital information*' factor ($\lambda_3 = .54$) rather than on the factor '*Evaluating digital information*' ($\lambda_2 = .30$). There were also examples of items with almost equal cross-loadings on two factors, indicating that they could be assigned to more than one factor. In particular, a number of items showed an overlap between the factors '*Evaluating digital information*' and '*Sharing and communicating digital information*'.

In sum, our first research question can be answered as follows: The hypothesized three-factor structure of TEDDICS was supported by ESEM. In addition, since ESEM provided a better model fit than CFA, an overlap between the three factors, as manifested in significant cross-loadings, exists. On the basis of these results, we proceeded with ESEM for further analyses.

4.2. Relations between TEDDICS and teachers' ICT use, self-efficacy, perceived usefulness, and age

On the basis of the three-factor ESEM model, we addressed our second research question by studying the correlations between TEDDICS and further teacher-related constructs (Fig. 2). As presented in Table 4, the correlations indicated positive associations between the three TEDDICS factors, ICT self-efficacy, ICT use, and perceived usefulness. In contrast, although insignificant, the correlations between age and TEDDICS were negative, suggesting that older teachers emphasize fostering students' digital skills less than younger teachers. The scale of '*Perceived usefulness: Collaboration*' showed a positive and significant relation to '*Sharing and communicating digital information*'; no significant relations to the other two factors of the TEDDICS scale were found. This finding indicated that the two subscales are interwoven and point out to the same aspect, namely collaborative use of ICT. In addition, the factor of '*Perceived usefulness: Information processing*' showed a significant

Table 4
Relations of teachers' emphasis on developing students' digital skills (TEDDICS) to further constructs.

Constructs	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. TEDDICS: accessing	1.00	.70 ^a	.53 ^a	.27 ^a	.48 ^a	.41 ^a	.13	.33 ^a	-.09
2. TEDDICS: evaluating		1.00	.64 ^a	.35 ^a	.52 ^a	.51 ^a	.10	.07	-.09
3. TEDDICS: sharing & communicating			1.00	.27 ^a	.61 ^a	.72 ^a	.26 ^a	.11	-.02
4. ICT self-efficacy for teaching				1.00	.42 ^a	.31 ^a	.15 ^a	.23 ^a	-.26 ^a
5. ICT use: teaching					1.00	.85 ^a	.32 ^a	.20 ^a	-.12 ^a
6. ICT use: collaboration						1.00	.35 ^a	.14	-.15 ^a
7. Perceived usefulness: collaboration							1.00	.56 ^a	-.03
8. Perceived usefulness: information processing								1.00	-.09
9. Age									1.00

Note. Correlations among latent variables are reported. In light of the model's complexity, the fit was defensible, $SB-\chi^2(443) = 1001.7^a$, CFI = .928, TLI = .914, RMSEA = .034, CI_{90-RMSEA} = [.031, .037], SRMR = .040. $N = 1072$.

^a $p < .01$.

correlation with TEDDICS factor *Accessing digital information*. Again, this result suggested that the two subscales relate to a common facet, which describes processes of retrieving and processing information. In sum, our findings indicated that high levels of TEDDICS were significantly related to high levels of self-efficacy, ICT use, and perceived usefulness.

4.3. Invariance and differences across gender and main subjects in TEDDICS

Establishing measurement invariance. To approach our third research question, we had to ensure that the measurement model obtained from research question 1 was comparable across gender and main subject groups. Hence, we first tested the three-factor ESEM model for different levels of measurement invariance across *gender* (Table 5). Given that the changes in CFI, TLI, and RMSEA were below the suggested cut-offs when comparing the configural (Model G-M1) and metric invariance models (Model G-M2), we had evidence that metric invariance was met. Moreover, the models of scalar and strict invariance (Models G-M3, G-M4) fitted the data well and the changes in fit statistics did not exceed the cut-offs, suggesting that both levels of invariance were also reached. Hence, assuring the highest level of invariance (strict invariance), comparisons of the factor means between male and female teachers can be employed.

The same analyses were conducted with teachers' main subject as the grouping variable (Table 5, Models S-M1 to S-M4). Given that the changes in model fit were again below the suggested cut-offs for all model comparisons and given that the fit statistics were defensible, we accepted strict invariance (Model S-M4). Consequently, factor mean comparisons could be employed to compare TEDDICS across the different main subjects.

Gender differences. On the basis of the strict invariance model, mean comparisons between male and female teachers were employed (Table 6). For the three TEDDICS factors, no significant gender differences were found. This finding indicated that male and female teachers emphasized developing students' digital information and communication skills almost equally.

Main subject differences. For teachers of different main subjects, significant mean differences were found across the three TEDDICS factors (Table 6). More specifically, the mean differences to teachers of humanities, language and arts as the reference group ranged between $d = -.24$ and $d = -.62$, indicating that teachers of mathematics, science, and other subjects tended to emphasize the three aspects of TEDDICS less. Keeping teachers whose main subjects were mathematics and science as a reference, teachers of other subjects (e.g., physical education) showed lower means in TEDDICS with low effect sizes ranging between $d = -.17$ and $d = -.31$. In fact, only the factor '*Evaluating digital information*' showed statistically significant differences and the lowest factor means.

Taken together, with respect to our third research question, measurement invariance was met and we found significant mean differences in TEDDICS in favor of teachers in the humanities, language, and arts. Nevertheless, we did not obtain evidence for gender differences.

5. Discussion

The present study was aimed at investigating TEDDICS with respect to its factorial structure (Research Question 1), the relations to teacher-related constructs (Research Question 2), and the generalizability and differences across gender and main subject groups (Research Question 3). Our overarching goal was to gather evidence on different aspects of construct validity that referred to internal validity, external validity, and the generalizability of TEDDICS across groups of teachers (for details on the underlying concept of validity, please refer to AERA, APA, and NCME (2014) and Messick, 1995).

5.1. Evidence on the internal validity of TEDDICS

Using ESEM we obtained empirical support for the hypothesized three-factor structure of TEDDICS. This finding lends support for the internal validity of the construct and adds evidence on the persistence of the factorial structure across different frameworks of digital competence (e.g., Calvani et al., 2012; Ferrari, 2013). Against this background, there is an

Table 5

Fit indices and comparisons of invariance models with gender (G) and main subject (S) as grouping variables.

Model	SB- χ^2 (df)	CFI	TLI	RMSEA	CI _{90-RMSEA}	SRMR	Δ CFI	Δ TLI	Δ RMSEA
<i>Invariance models across gender (G)</i>									
G-M1: configural invariance	161.7 (66)*	.972	.944	.052	[.042, .062]	.025	–	–	–
G-M2: metric invariance	178.1 (93)*	.975	.965	.041	[.032, .050]	.036	+ .003	+ .019	– .011
G-M3: scalar invariance	198.4 (102)*	.972	.964	.042	[.033, .051]	.039	.000	+ .020	– .010
G-M4: strict invariance	210.6 (114)*	.972	.967	.040	[.031, .048]	.041	.000	+ .023	– .012
<i>Invariance models across main subjects (S)</i>									
S-M1: configural invariance	251.8 (99)*	.957	.914	.066	[.056, .076]	.029	–	–	–
S-M2: metric invariance	296.5 (153)*	.960	.948	.051	[.042, .060]	.046	+ .003	+ .034	– .005
S-M3: scalar invariance	343.5 (171)*	.951	.944	.053	[.045, .061]	.052	– .006	+ .030	– .013
S-M4: strict invariance	394.5 (195)*	.944	.943	.054	[.046, .061]	.059	– .013	+ .029	– .012

Note. SB- χ^2 (df) = Satorra-Bentler corrected χ^2 value with df degrees of freedom (Satorra & Bentler, 2010), CI_{90-RMSEA} = 90% confidence interval of the RMSEA, tested against .05. Positive values of Δ CFI and Δ TLI, and negative values of Δ RMSEA indicate an improvement in model fit. Adjacent models were compared. N = 1072.

ns: statistically insignificant, * $p < .01$.

Table 6

Differences in latent means across gender and main subject groups.

Group	Factor 1: accessing digital information	Factor 2: evaluating digital information	Factor 3: sharing & communicating digital information
Gender			
Males	.00 (.00)	.00 (.00)	.00 (.00)
Females	.32 (.13)	.15 (.08)	.24 (.12)
Main subject			
<i>Reference: humanities, languages & arts</i>			
Humanities, languages & arts	.00 (.00)	.00 (.00)	.00 (.00)
Mathematics & science	–.35 (.11) ^a	–.38 (.08) ^a	–.24 (.10)
Other subjects (e.g., physical education)	–.42 (.16) ^a	–.62 (.10) ^a	–.48 (.14) ^a
<i>Reference: mathematics & science</i>			
Mathematics & science	.00 (.00)	.00 (.00)	.00 (.00)
Other subjects (e.g., physical education)	–.17 (.15)	–.31 (.10) ^a	–.30 (.16)

Note. The reported differences can be interpreted as effect sizes (Cohen's d). Standard errors are shown in brackets. N = 1072.

^a $p < .01$.

alignment between the *structure* of students' digital information and communication skills and teachers' emphasis on developing them. In light of the factorial structure, we argue that studying the three factors of TEDDICS provides more detailed information on teachers' classroom practice than unidimensional models which only provide information on the overall degree of emphasis and use. For instance, our data indicated a fairly low level of emphasizing 'Evaluating digital information' in classrooms. This finding points out the importance of reviewing, monitoring, and critical thinking in digital information processing (Strømsø & Bråten, 2014). Our differentiated view on TEDDICS may therefore reveal the strengths and weaknesses of classroom instruction with ICT.

Besides the differentiation into the three TEDDICS factors, the data suggested the existence of construct overlaps, manifested as item cross-loadings in an ESEM. From a statistical point of view, we conclude that ESEM provides a better representation of the factorial structure than models without cross-loadings (Marsh et al., 2009; Muthén & Asparouhov, 2012). Loosening the assumption of perfect item-factor links leads to more robust measurement models that do not overestimate the correlations between factors (Marsh et al., 2014). From a substantive point of view, we have evidence that the hypothesized overlap between the factors exists. This finding appears reasonable, since the three factors were all related to specific activities in the context of dealing with digital information. For example, evaluating digital information may be regarded as a prerequisite of sharing and communicating the information (e.g., Ferrari, 2013). In consequence, researchers need to take into account that teachers' reports on the emphasis of these two skills may go together.

Our findings support considering TEDDICS as multidimensional, comprising three related but distinct factors that represent students' skills of mastering digital information.

5.2. Evidence on the external validity of TEDDICS

As a step of assuring external validity of the TEDDICS measure (Messick, 1995), we examined the relations between TEDDICS, the frequency of ICT use for teaching and learning, ICT self-efficacy, perceived usefulness of ICT, and teachers' age.

The correlations between the *frequency of ICT use* and TEDDICS were positive, suggesting that ICT learning opportunities in classrooms are linked to the qualitative measure concerning emphasis of developing students' digital skills. Differentiating between the three TEDDICS factors and the two factors of ICT use revealed only moderate differences in the correlations. Yet, the highest correlation was found for the factors that were assigned to collaboration ($\rho = .72$). This result was rather expected and consolidates evidence on external validity. Although the correlations between teachers ICT use and TEDDICS were high, we emphasize that the two constructs are *empirically distinct* (the correlations are not perfect). In addition, they are also *conceptually distinct*: As ICT use was measured by teachers' reports on the frequency of their ICT use for different purposes; it represents a *quantitative* aspect of ICT use. Considering the TEDDICS scale, teachers were asked to rate the degree to which they emphasize fostering students' digital skills, which reflects a *qualitative* aspect (Fraillon et al., 2014). Consequently, we argue that research on ICT integration in classrooms may assess the two constructs jointly in order to get detailed information on different aspects of teachers' ICT use.

ICT self-efficacy for teaching reflects teachers' beliefs in their competencies of using ICT for teaching and is considered a personal characteristic (Paraskeva, Bouta, & Papagianna, 2008). TEDDICS showed positive correlations with ICT self-efficacy, indicating that teachers who believe in their competence to use ICT for teaching purposes emphasize fostering students' digital skills. Feeling competent in using ICT for teaching can be regarded as a precondition for using ICT in classrooms and furthermore for emphasizing the development of the very skills that teachers should have developed themselves (Teo, 2008). Similar relations were reported between self-efficacy and ICT integration (e.g., $r = .18-.66$; Akarsu & Akbiyik, 2012; Chen, 2010; Kreijns et al., 2013). Again, the positive correlations between self-efficacy and TEDDICS confirm our expectations and thus lend evidence on external validity.

Perceived usefulness is described as the degree to which teachers believe that using technology would enhance their job performance (Davis, 1989; Teo, 2011). This construct can also be regarded as a part of teachers' belief system. Whereas self-efficacy refers to self-beliefs, perceived usefulness refers to beliefs about an external object or a method (Davis, 1989; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Our analysis showed significant relations between the TEDDICS factors *Accessing digital information* and *Sharing and communicating digital information* with the two corresponding perceived usefulness factors of fostering students' *collaboration* and students' *information processing* skills. The correlations are comparable to those found in studies that reported on relations between perceived usefulness and the integration and use of ICT (e.g., $r = .26-.56$; Igbaria et al., 1996; Venkatesh et al., 2003). In consequence, the more teachers perceive ICT as useful for teaching and learning, the more emphasis they put on developing students' digital skills. In addition, our results point out that only the correlations between the corresponding factors of ICT use and perceived usefulness were significant. This may imply that perceived usefulness does not necessarily reflect teachers' general perceptions of ICT but seems to be more sensitive to the specific, ICT-related content being measured.

Teachers' age and TEDDICS were not significantly related, yet there was a tendency towards negative correlations. Hence, older teachers tend to show less TEDDICS than younger teachers. This result may be explained by the fact that older teachers use ICT less frequently in classrooms (O'Bannon & Thomas, 2014), as indicated by the negative correlation between age and ICT use in our results. Moreover, they regard themselves as less competent in using ICT for teaching and learning purposes, as indicated by the correlation between age and ICT self-efficacy. Existing research has confirmed these negative relations for teachers' age and their attitudes towards ICT and the use of ICT (Morris & Venkatesh, 2000; O'Bannon & Thomas, 2014; Scherer et al., 2015; Vanderlinde et al., 2014; Venkatesh et al., 2003).

5.3. Invariance and differences across gender and main subjects in TEDDICS

Tests of measurement invariance on gender and main subjects supported strict invariance, meeting the premise for making comparisons across groups (Millsap, 2011). Hence, the assessment of TEDDICS does not function differently across gender or main subject groups. This result points to the generalizability of the construct and lends additional evidence on its validity (Messick, 1995).

Regarding the gender differences, our findings align with results of a number of studies that did not observe gender effects on ICT-related attitudes, beliefs, or use (Antonietti & Grigoriotti, 2006; Sang et al., 2010; Shapka & Ferrari, 2003; Yuen & Ma, 2002). Moreover, there is an alignment between our findings and the Teaching and Learning International Survey (TALIS) 2013 results on the insignificant relation between gender and ICT use in Norway (OECD, 2014). However, research on gender effects draws no clear picture on the significance of differences and although some researchers have reported differences between males and females in their attitudes towards ICT (Oosterwegel et al., 2004; Shashaani, 1993), there is evidence that the gender gap in ICT-related constructs is decreasing (Schumacher & Morahan-Martin, 2001). Since there is no general pattern in gender differences, we argue that they may vary across constructs and cohorts (OECD, 2014; Volman & van Eck, 2001). For TEDDICS, we did not find these differences.

On the contrary, our results revealed differences between teachers across their main subjects (i.e., humanities, languages and arts, mathematics & science, and other subjects). Teachers of the humanities, languages and arts tend to emphasize the development of students' digital information and communication skills more than teachers in the two other subject groups. Although these results may contradict some of the existing research which found differences in constructs that are closely related to TEDDICS in favor of STEM subjects (e.g., perceived usefulness and ICT integration; Schmid et al., 2014; Hennessy et al., 2005), our results support the tendency of integrating ICT more in the humanities, languages and art, which was also reported in TALIS 2013 (OECD, 2014). Accounting for the different subject cultures, we regard this as not very surprising

because some of the digital skills that are related to retrieving and processing digital information are considered crucial elements of specific subject matters in humanities, languages and art (Fraillon et al., 2014). Although these skills are also important for mathematics and science they may be integrated to a lesser extent (Donnelly et al., 2011). Moreover, the subject differences in TEDDICS may be due to differences in teachers' technological pedagogical content knowledge and their beliefs in the usefulness of ICT for subject-specific teaching (Teo, 2014; Voogt et al., 2012). Future research may therefore be concerned with the effects of technological pedagogical content knowledge and teachers' beliefs on TEDDICS across subjects.

5.4. Limitations and future directions

The present study has a number of limitations: First, we investigated TEDDICS on the basis of self-reports. These reports reflect teachers' perceptions of emphasizing students' digital skills and may therefore differ from the actual classroom practice. In order to provide further information on the classroom practices, future research may explore them by using observational data (e.g., video-based observation). Second, since there was no direct link between teachers and students in ICILS 2013 (Fraillon et al., 2014); it was not possible to investigate the impact of TEDDICS on students' actual digital skills. This information would be desirable in order to gain thorough knowledge about the relation between classroom practice and TEDDICS. Moreover, intervention studies may even provide causal information on this relation, impacting the design of educational material that is aimed at developing students' digital skills and improving teachers' technological pedagogical skills.

6. Conclusion

Our study provides evidence for the internal and external validity of the newly studied construct, TEDDICS. In particular, the factorial structure of *teachers'* emphasis is best represented by an exploratory structural equation model that differentiates between three factors, aligned with the a-priori assumptions on the structure of *students'* digital competence (e.g., Calvani et al., 2012; Kuiper et al., 2005). In consequence, we argue that research on the relation between teachers' ICT classroom practice and students' digital skills may benefit from this alignment of constructs, because a direct correspondence between them can be established. Moreover, the relations between TEDDICS and further constructs such as the frequency of ICT use, teachers' ICT self-efficacy, perceived usefulness, and age advocate construct validity. With respect to the modeling of gender and main subject differences, the measurement of TEDDICS remains invariant, supporting the generalizability and sensitivity of the construct to the different groups of teachers. We consider TEDDICS a construct that could be implemented as a qualitative component of ICT use in future research on technology acceptance and integration. Our study points out the relevance of the construct for studying the link between teachers' classroom practice and students' digital skills.

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