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# Understanding teaching professionals' digital competence: What do PIAAC and TALIS reveal about technology-related skills, attitudes, and knowledge?

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ABSTRACT

In an ever-evolving technological landscape that challenges teaching professionals' digital competence, this study complements previous studies by providing an overall picture of teaching professionals' digital competence. We employed regression models on two large-scale assessment data sets on teachers from 11 countries—namely, the Teaching and Learning International Survey (TALIS; n = 50,800) and the Programme for the International Assessment of Adult Competencies (PIAAC; n = 2590)—to investigate through the theoretical lens of digital competence how teaching professionals' skills, attitudes and knowledge distribute and relate, and how they are associated with personal and contextual factors. Our results found notable variation in teaching professionals' skills and knowledge but less variety in attitudes. The respondents generally recognised the importance of digital technologies in teaching regardless of their background. Older professionals often showed weak skills, but they also recognised the need for professional development in using digital technologies. An important result of this study is a better understanding of digital competence from the teaching professional's perspective. Our findings contribute to further developing theories and practices related to teaching professionals' skills, attitudes and knowledge.

## 1. Introduction

Generally, *digital competence* can be defined as a set of skills, knowledge, and attitudes that enable the individual to achieve goals using digital technologies in various life contexts (Baartman & de Bruijn, 2011; Ferrari et al., 2012). Technological change challenges teaching professionals at two levels: first, to develop their own digital competences, and second, to develop instructional activities that equip all students with the competences needed to succeed in the digitalised world. For example, alongside supporting *traditional* literacy skills, teachers have to support literacy skills in digital settings (Billett et al., 2018; Harteis, 2019; Tsai & Chai, 2013). Regarding the digital skills of teachers, there is a critical notion that teaching professionals seem to face challenges, e.g., they possess weaker problem-solving skills for technology-rich environments (TRE) than adults working in other sectors (Hämäläinen, De Wever, Nissinen, & Cincinnato, 2019). Despite this critical notion, we need to remember that the technology skills possessed by teachers are different from their teaching competences in digital settings. In this study, we consider the digital competence of teaching professionals as a major premise that comprises digital skills, attitudes, and knowledge (Fig. 1) (Ferrari, 2012; Redecker, 2017; Spiteri & Rundgren, 2020; Tondeur et al., 2018).

The current development calls for a deeper understanding of if and how large-scale data sets can be applied to better understand the digital competence of teaching professionals. Large international survey studies, such as the Programme for the International Assessment of Adult Competencies (PIAAC), the Teaching and Learning International Survey (TALIS), and the Programme for International Student Assessment (PISA), administered by the Organisation for Economic Co-operation and Development (OECD), provide a significant amount of information for research. However, these data sources are underused. To date, the digital competences of teaching professionals have been

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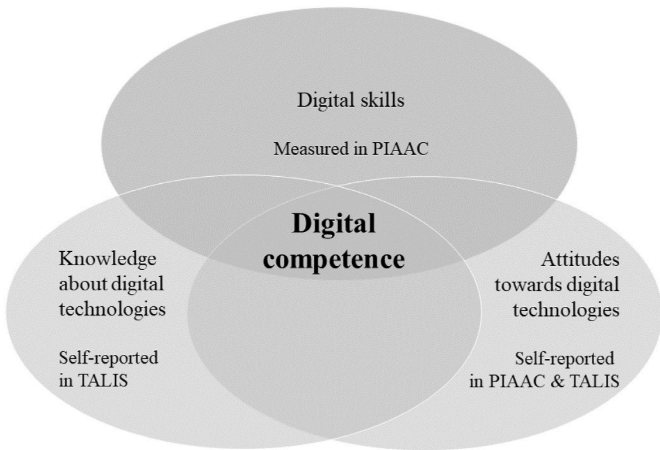


**Fig. 1.** The three factors associated with the digital competence.

investigated mostly via small-scale case studies or large sample studies using self-reports (Koh et al., 2017; Wastiau et al., 2013). In the context of large-scale assessment studies, frequency of use of technology and the technology-related attitudes of teachers have been investigated most extensively by the Second Information Technology in Education Study (SITES, 1998–2006) and its successor, International Computer and Information Literacy Study (ICILS 2013/2018), studies of the International Association for the Evaluation of Educational Achievement (IEA). However, much like most similar studies, these research rely on self-reported data, and the number of participating countries has so far been rather small. In the area of digital competence, the use of self-reports can easily lead to participants overrating their competence (Merritt et al., 2005; Talja, 2005). To better understand the variation in the digital competences of teaching professionals, we explore both measured and self-reported factors that constitute the digital competence of teaching professionals (e.g., skills, attitudes, and knowledge regarding technology) via two large-scale data sets (Fig. 1). To date, PIAAC is the only study that has measured the digital skills of adults with a considerably large number of participants from European countries. TALIS is the first and only international survey focused on the learning environment and the working conditions of teachers, and it fills important information gaps in the international comparisons of education systems. Thus, in this study, the large-scale surveys of PIAAC and TALIS were selected for further analysis because their extensive sampling allows for a comprehensive overview of European countries in the current debate on developing digital competences.

This study illustrates and explores if and how these two large-scale surveys can be applied to empirically investigate the concept of digital competence. First, we discuss the concept of digital competence to make sense of how we understand and operationalise the digital skills, attitudes, and knowledge of teaching professionals. Second, we use a variation of approaches to analyse the data from PIAAC and TALIS to unveil the picture that these two data sets paint of the technology-related skills, attitudes, and knowledge of teaching professionals (Fig. 1). We also discuss our conceptual and empirical exploration from a critical perspective and conclude by elaborating on the implications of our findings for shaping digital transformation in schools and developing educational practices and the digital competences of teaching professionals in the emerging technological landscape.

## 2. Theoretical background

Previous research indicates that several personal and contextual factors are associated with digital competence. For example, a cognitive study conducted in Finland found that male teachers are more highly skilled at utilising information and communications technology (ICT) resources and tools than female teachers (Kaarakainen et al., 2018). In the ICILS, male teachers also showed higher ICT self-efficacy than female teachers (Fraillon et al., 2019; Gebhardt et al., 2019, p. 73). Furthermore, Almerich et al. (2016) found that gender and ICT use at work are significantly related to both technological (general) and pedagogical (integration of ICT into teaching practice) competences, while frequency of ICT use outside of work is related only to technological competence. However, gender differences seem to be complex (Abbiss, 2008), as Hatlevik and Hatlevik (2018) did not find significant associations between the gender of teachers and ICT use or ICT self-efficacy—neither did Tondeur et al. (2018)—among pre-service teachers. Some other background variables also seem to be relevant. The ICILS (Fraillon et al., 2019) found that teachers under 40 years old were more confident of their ICT skills than older teachers (cf. Tondeur et al., 2018). Predominantly, teachers used typical office tools, such as tools for word processing and making presentations (European Commission, 2019). Thus, the software used by teachers does not seem to differ from the most common software used in any office. In the ICILS, teachers of subjects focused on teaching ICT-related skills (ICT, language of the school, and the sciences) placed more emphasis on various content and skills related to ICT use. The weakest emphasis on ICT skills recorded was among teachers of mathematics, vocational subjects, and physical education (Fraillon et al., 2019).

In addition to personal and contextual factors, probably the best-known method of investigating the readiness of teaching professionals in technology-enhanced contexts is the Technological Pedagogical Content Knowledge (TPACK) framework and its knowledge components (Koehler & Mishra, 2009; Lachner et al., 2019; Niess, 2011; Voogt et al., 2013). TPACK is an interwoven form of knowledge that binds together three *core* knowledge components: technology, pedagogy, and content. Currently, several TPACK surveys have been constructed and administered (Ifinedo et al., 2020; Luik et al., 2018; Schmid et al., 2020). The focus of these studies is generally to capture a teacher-knowledge framework for technology integration via self-report (Backfisch et al., 2020; Nelson & Hawk, 2020; Scherer et al., 2018; Taimalu & Luik, 2019). There is thus a need to utilise tests that measure the readiness of teaching professionals in technology-enhanced contexts via tasks that imitate authentic situations on a large scale, e.g., international large-scale assessments. In these large-scale assessments, the concept of *competence* has traditionally been used to describe the individual capabilities necessary for participation in modern societies (OECD, 2012). There is also a long history of investigating the competences of teaching professionals in the field of professional development (Andersson & Köpsén, 2015; Billett, 1995, 2009, pp. 1333–1349). Because PIAAC measures and relies on the concept of competence, we complement TPACK studies by turning our attention to digital competence (Fig. 1). Below, we briefly elaborate constituents of digital competence (skills, knowledge, and attitudes) as defined in this study.

### 2.1. Skills

The term, *skills,* overlaps with the concept of competence, and these terms are often used interchangeably. Skills can be distinguished as an organised sequence of motor and cognitive activities that include the organisation of movement and symbolic information (Baartman & de Bruijn, 2011; Fitts & Posner, 1967). Research on the digital skills of teaching professionals has focused on technical ICT use (Tondeur et al., 2018; van Laar et al., 2017), which can be seen as a prerequisite for taking advantage of technology-enhanced instructional practices. However, there has recently been a shift towards a more holistic perspective, as thinking, problem-solving, and learning in digital environments have a more profound impact on the ability of the individual to function in a technology-rich society than on the ability to simply use a specific application or software (Van Laar et al., 2017). It is thus vital to also consider the digital skills of teaching professionals more holistically to understand their potential for shaping digital transformation in schools (cf. Claro et al., 2012; van Laar et al., 2017). We consider digital skills that have technical, information management, creativity, critical thinking, and problem-solving dimensions (Van Laar et al., 2017, p. 583).

In this study, we operationalise digital skills as problem-solving (PS) skills in TRE, as measured in the PIAAC study, which remains the most comprehensive test measuring the skills of adults. The PIAAC reports that PS-in-TRE involves using digital technology, communication tools, and networks to acquire and evaluate information, communicate with others, and perform practical tasks. The PIAAC PS survey measured the ability of adults to solve problems for personal, work, and civic purposes by setting up appropriate goals and plans as well as by accessing and making use of information through computers and computer networks (OECD, 2019a). In practice, the measure of PS-in-TRE comprises: (a) skills associated with the use of computers (e.g., keyboard skills), (b) an understanding of the structure of the digital environment (e.g., files, folders, and hyperlinks), and (c) the ability to effectively use and manipulate digital information (e.g., save, edit, submit, or send). While PS-in-TRE does not focus on digital skills specific to the teaching profession, it does focus on tasks that everyone in society needs to participate in (including schools) using digital tools. These generic skills can be considered prerequisites for any domain-specific digital competence. These skills are also emphasised by the EU Commission (Redecker, 2017) and are considered key skills for students (Fraillon et al., 2019). It is well known that the digital skills of teaching professionals are interwoven with their attitudes towards technology and their knowledge of technology (Spiteri & Rundgren, 2020). Next, we elaborate on and operationalise attitudes in the digital competence of teaching professionals (Heinonen, Jääskelä, Häkkinen, Isomäki, & Hämäläinen, 2019).

### 2.2. Attitudes

In addition to a skill-based focus, it is also important to regard the attitudes and beliefs of teaching professionals towards digital technologies because they influence the actions of individuals and play an important role in the learning process (Funkhouser & Mouza, 2013; Prestridge, 2012; Van Braak et al., 2004; van Dinther et al., 2011). Bereczki and Kárpáti (2018) define beliefs as representations of reality that are not necessarily substantiated by the empirical world; thus, beliefs in this context represent individuals' perceptions of their capabilities to plan and execute specific behaviour: what individuals think they *can* do, rather than what they *will* do. Attitudes (Baartman & de Bruijn, 2011), in turn, can be seen as clusters of beliefs around an object or situation that guide the behaviour of an individual (Ajzen, 2001; Pajares, 1992). Based on the study by Instefjord and Munthe (2017), in this article, we see attitude as the sum of the beliefs held by the individual.

According to Aslan and Zhu (2017), *attitude* is defined as a person's predisposition to respond positively or negatively to a person, object, or event (cf. Ajzen, 1988). In practice, this means that a teaching professional can have different negative and/or positive beliefs about the use of technology, about his or her students, and about his or her self-efficacy as a teacher or educator. The attitude of a teacher towards integrating technology in the classroom will be based on the overall evaluation of his or her beliefs (Instefjord & Munthe, 2017). Thus, it is unsurprising that in the context of digital technologies and teaching professionals, the two constructs of *attitudes* and *beliefs* are positively associated (Scherer et al., 2018). Based on previous research, we also know that teacher self-efficacy and the ease of technology usage are important predictors of the attitude of teachers towards applying ICT in education (Krause, Pietzner et al., 2017; Yeşilyurt et al., 2016). In the context of the digital competence of teaching professionals, attitudes are often referred to as internal or second-order barriers to technology integration in classrooms, as they are relatively susceptible to change (Ertmer et al., 2012; Makki et al., 2018; Nelson et al., 2019). In the next sub-section, we use the concept of *attitudes as an upper concept*—, bearing the meaning of the concept of *beliefs* (incl. such as self-efficacy beliefs) in mind as part of it.

Our intention is to deepen the understanding of the role of attitudes in reviewing digital competence (Fig. 1). As the attitudes of teaching professionals towards digital technologies are associated with self-efficacy, use, and valuing of technology by teachers (Kazan & ELDaou, 2016; Letwinsky, 2017; Joo et al., 2018), we operationalised teaching professionals' attitudes towards digital technologies based on items in the PIAAC and TALIS self-reported data (whether they think they possess the digital skills needed to do their jobs well, supporting student learning through the use of digital technology, letting students use ICT for projects or class work, rating the importance of investing in ICT). Beyond skills and attitudes, our study is grounded in the notion that teaching depends on flexible access to integrated, well-organised knowledge from various domains, including information on student thinking, learning and interaction, subject matter knowledge, and increasingly, knowledge on digital technologies (Putnam & Borko, 2000).

### 2.3. Knowledge

Throughout the history of technology-enhanced learning, different approaches have been developed to capture and understand knowledge in various teaching contexts, such as knowledge building (Scardamalia & Bereiter, 2010) in the context of professional development (Chai & Tan, 2009) and TPACK (Koehler & Mishra, 2009). Generally, knowledge can be distinguished as *knowing that* and *knowing how*. The classification *knowing that* refers to knowledge of definitions, concepts, and facts, while *knowing how* refers to knowing how to do something (without necessarily performing the actions) (Baartman & de Bruijn, 2011; Miller, 1990). It is generally agreed that knowledge is interwoven with skills and attitudes (Fig. 1), as each kind of knowledge is something that the individual can report on but not necessarily something that they wish to (attitude) or can (skills) perform in practice. Knowledge of digital technologies concerns *what*, *how* and *why* such technologies are used (Spiteri & Rundgren, 2020, p. 122). In the context of the digital competences of teaching professionals, knowledge of the functions and benefits of digital technologies and their applications can be seen as a precondition for the successful integration of digital technologies into education (Jaipal & Figg, 2010; Voogt et al., 2013).

However, we have to consider that knowledge of technologies is a challenging target for research, as the technological landscape is evolving rapidly (Koehler et al., 2012; Voogt et al., 2013). In practice, any research instrument focused on technology-related knowledge needs to be constantly updated. To address this challenge of up-to-date instruments, implicit methods of examining the digital technology knowledge of teaching professionals may be needed. Because of this, using large-scale surveys to study knowledge is particularly challenging. After critical and careful consideration, we operationalised the knowledge of digital technologies of teaching professionals based on three items from the TALIS data: knowledge of digital technologies that teaching professionals have acquired from formal education, introduction to the workplace, and professional development. Grounded in the TALIS data, *professional development* refers to activities that aim to advance the expertise of teaching professionals, and ultimately, improve their teaching practices. It thus involves the procedures employed by teaching professionals in learning how to learn and in transforming their knowledge into practices that benefit the growth of their students (OECD, 2014).

## 3. Aims

This research complements previous case studies and large-scale studies that use self-reports. For this purpose, we explore if and how two large-scale data sets (PIAAC and TALIS) can be applied to provide an overarching perspective of the digital competences of teaching professionals. We seek to investigate the variations and relations between the measured skills of teaching professionals in practice and their self-reported attitudes and knowledge with respect to digital technologies (Fig. 1). We answer the following research questions (RQs):

RQ1: How are the skills, attitudes, and knowledge of teaching professionals distributed?

RQ2: How are the skills, attitudes, and knowledge of teaching professionals related?

After identifying the digital competences of teaching professionals (digital skills, attitudes towards digital technologies, and knowledge of digital technologies), in the second stage, we explore how personal and contextual factors (Section 4.3) are associated with these digital competences by answering the following research question:

RQ3: How are the skills, attitudes, and knowledge of teaching professionals related to personal and contextual factors?

## 4. Materials and methods

We have divided this section into four sub-sections. In Section 4.1, we describe the parts of the PIAAC and the TALIS data sets used in this study. In Section 4.2, we elaborate on how we identified the constituents of digital competence based on the available data. In Section 4.3, we describe the personal and contextual factors used in this study. In Section 4.4, we present the statistical analyses conducted to answer our RQs.

### 4.1. Data

To address the RQs, we consider the PIAAC and TALIS data sets. PIAAC is a large-scale assessment focusing on the skills of adults. The main aim of the PIAAC PS-in-TRE assessment is to investigate the ability of participants to use technology effectively and proficiently to solve 21st-century problems (for further description of PS-in-TRE tasks, see Section 2.1, (OECD, 2013a)). In addition, the respondents in PIAAC filled out a comprehensive questionnaire on their sociodemographic and educational backgrounds, and employment histories and attitudes (OECD, 2013b). We employ the PIAAC data collected in 2011 and 2012 in Round 1 of PIAAC Cycle 1. Round 1 is the largest available international survey on the skills of adults, with data drawn from some 166,000 respondents aged 16–65 years, from 24 countries. TALIS is an international survey of teachers and school leaders. Its main goal is to generate internationally comparable information for the development of policies focused on school leaders, teachers, and teaching, with an emphasis on aspects that affect student learning (OECD, 2019b). A total of 48 countries participated in the study in 2018, and the number of respondents was around 164,000. The focus of TALIS was lower secondary education, but a few countries also administered the survey to teachers in primary and upper secondary education. The survey asked teachers questions about their work lives at school, ranging from their school environment and how they interacted with colleagues to their teaching practices and participation in continuous professional development (OECD, 2019c).

We concentrate on 11 European countries (Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, the Netherlands, Norway, the Slovak Republic, Sweden, and the United Kingdom) that participated in both the PIAAC assessment of PS skills of adults in TRE and the TALIS. We do not consider between-country comparisons but treat the data of the selected countries as a pooled data set. For the PIAAC data, we restrict our analysis to the respondents working as professionals in the education industry, as defined in the industry classification of the United Nations, the International Standard Industrial Classification (ISIC), and the occupation classification of the International Labour Organisation, the International Standard Classification of Occupations (ISCO). The resulting data set was drawn from 2590 respondents. Approximately 93% of the respondents were teachers, 29% worked in pre-primary or primary education, and 26% in secondary education (both general and vocational). About 13% worked in higher education, and 11% in other kinds of education, including adult education. Detailed information on the workplace was unspecified or missing for approximately one-fifth of the teachers. The other respondents worked in administrative or supporting positions within the field of education. For brevity, going forward, we call all the respondents *teaching professionals*. The TALIS data was drawn from 50,800 respondents, 22% of whom worked in primary education, 69% in lower secondary education, and 9% in upper secondary education.

### 4.2. Identifying the digital competences of teaching professionals

We investigated the digital competences of teaching professionals from the perspective of the socially situated nature of learning. Our starting point was that the digital competences of teaching professionals are always related to their personal lives and work history. To make sense of the phenomenon at hand, we conducted a thematic analysis (Braun & Clarke, 2006) of the variables in the PIAAC and TALIS data sets (OECD, 2018; OECD, 2019a). We used previous research on the competences of teaching professionals as a starting point for the thematic analysis. As described in the theoretical background (Chapter 2), previous studies on competence lie at the crossroads of research on the skills, attitudes, and knowledge of teaching professionals. Thus, we identified three clusters of variables indicating digital competences: (1) variables related to skills, (2) variables related to attitudes, and (3) variables related to knowledge (Fig. 1).

In analysing the skills of teaching professionals (Cluster 1; Section 2.1), we utilised data from the PIAAC study. In PIAAC, the digital skills of the respondents were assessed via a PS-in-TRE test taken on a laptop. The test scores measuring skills were then created based on item response theory (IRT) and are called *plausible values*. This is the usual way to construct measures of the latent proficiencies of an individual in all international large-scale assessments (Berezner & Adams, 2017; Von Davier & Sinharay, 2014; Mislevy et al., 1992). The scores are based on the success of each individual on the administered test items, given the level of difficulty and the background information on the respondents (OECD, 2019a, Chapter 17). Success on difficult items yields a higher score than success on easy items. An adequate statistical analysis of plausible values requires a specific methodology based on multiple imputations (OECD, 2019a, Chapter 18.3). The plausible values measuring PS-in-TRE skills are classified into four proficiency levels: 0, 1, 2, and 3, where Level 1 is an elementary level and Level 3 indicates deep proficiency. In this study, we base our analyses of the skills of teaching professionals on these proficiency levels, focusing on strong skills (Level 3) and weak skills (Level 1 or lower).

In examining the attitudes of teaching professionals towards digital technologies (Cluster 2), we turned primarily to the TALIS data set. However, the TALIS teacher questionnaire contains relatively few items that strictly measure attitudes (or beliefs) in the sense described in Section 2.2. After a critical investigation, we selected three items, which concerned the self-reported ability of the respondent to support student learning through the use of digital technology, allowing students to use ICT for projects or class work, and the importance placed on investing in ICT for educational purposes (Appendix 1). Furthermore, we utilised one question from the PIAAC background questionnaire concerning whether the respondents believed they possessed the computer skills needed to do their jobs adequately.

A similar investigation of the TALIS questionnaire was conducted for selecting items as indicators of the respondents' knowledge of digital technologies (Cluster 3; Section 2.3). We eventually decided to proceed with four items. These concern the inclusion of ICT in the formal education or training of the respondents, self-assessed preparedness for using ICT in teaching, need for professional development in digital technology, and participation in ICT-related professional development. The detailed wording of the TALIS items employed are presented in Appendix 1.

We initially examined the possibility of creating composite scores using factor-analytic methods from the selected TALIS items measuring attitudes (Cluster 2) and knowledge (Cluster 3) to be used as response variables in data analyses. However, some of the selected items showed weak correlation with the others, making it impossible to obtain composite scores with satisfactory reliability. Thus, we performed the analyses for individual items only. The observed associations between the considered items are reported in Section 5.2 and Appendix 3.

All the variables in clusters 1–3 served as dependent variables in our analyses for the three research questions, addressing the digital skills, attitudes towards digital technologies, and knowledge of digital technologies (RQ1) among teaching professionals, as well as relations between these attributes (RQ2) and their associations with personal and contextual factors (RQ3).

### *4.3. Identifying personal and contextual factors associated with the digital competences of teaching professionals*

Based on previous research (Chapter 2), we decided to look at some personal factors constituting digital competence (Fig. 1), such as gender and age, as well as contextual factors, such as the subject to be taught and teaching experience. We selected nine PIAAC variables and four TALIS variables as the personal and contextual factors in our analyses for RQ3. They served as independent variables in regression models explaining variation in the variables measuring skills (Cluster 1), attitudes (Cluster 2), and knowledge (Cluster 3). In the analyses of PIAAC data, with dependent variables from Cluster 1 and Cluster 3, the nine personal and contextual explanatory factors broadly fall into two groups: (1) socio-economic and demographic variables, and (2) variables related to learning attitudes and the use of digital technologies. The sociodemographic variables include gender, age group, language background (whether the respondent is a native speaker of the testing language), number of books in the respondent, educational level, and field of study of the highest degree obtained (dichotomised as education/other). Other factors include attitude towards learning new things and regularity of ICT use, both at work and outside of work. The categories of these personal and contextual factors, which appeared to be the most significant based on data analyses, are presented in detail in Tables A1 and A2 in Appendix 2. For TALIS, the four independent variables in the models are gender, age group, level of formal education completed, and the primary subject taught by the respondent in the school year when the survey was conducted. The categories of the factors and the respective numbers of observations are presented in Table A3 of Appendix 2. Next, we present the statistical analyses used to address RQ1–RQ3.

### *4.4. Statistical analyses*

To address RQ1, we examined the percentage distributions of the dependent PIAAC and TALIS variables in Cluster 1 (skills), Cluster 2 (attitudes), and Cluster 3 (knowledge). Recall that we examined the distribution of skills via proficiency levels derived from the PS-in-TRE plausible values in the PIAAC, and that proficiency Level 3 represents strong skills and Level 1 and Level 0 were merged into one group representing weak skills. Due to the complex sampling designs of PIAAC (OECD, 2019a) and TALIS (OECD, 2018), all computed statistics were survey weighted.

We analysed the relations (RQ2) between teaching professionals' skills (Cluster 1), attitudes (Cluster 2), and knowledge (Cluster 3) using cross-tabulations and correlation coefficients. With the PIAAC data, we used cross-tabulation in examining the association between measured PS-in-TRE skills (Cluster 1) and the respondents' views of possessing skills needed at work (Cluster 2). With the TALIS data, we examined the magnitude of associations between items representing the attitudes (Cluster 2) and knowledge (Cluster 3) of the respondents using Pearson correlations. However, because there are ordinal and even binary variables, we performed alternative analyses using Cramér's V statistic, which is appropriate for cross-tabulations and can also detect non-linear associations. Again, survey weights were applied in all computations.

For RQ3, we employed linear and logistic regression analyses in examining associations between personal and contextual factors (Section 4.3) and measures of skills, attitudes, and knowledge. The significance of the associations between skills, attitudes, and knowledge and the background factors were tested within regression models. The regression analyses were carried out with survey procedures that produced correct standard errors and significance tests using complex samples; in particular, the school-level clustering in TALIS needed to be considered. Additionally, in analysing the skills (Cluster 1), we employed the plausible values methodology.

As the data sets comprised 11 countries, the possible mean differences between countries may distort the analyses of pooled data. To control for this, we introduced a fixed categorical country effect in all regression models. However, as our RQs do not deal with between-country differences, we do not report them in the results tables. The explanatory power of the background variables in the regression models was assessed using the increase in R-squared, obtained by adding the background variables to the baseline model containing only the country effects.

The statistical computations were performed in SAS software, primarily with the survey analysis procedures SURVEYMEANS, SURVEYREG, and SURVEYLOGISTIC. For plausible values analyses, a specific SAS macro PIAAC Tool (Denis, 2014) provided by the PIAAC Consortium and available at the PIAAC website of the OECD was used.

## 5. Results

We have structured this section based on our three RQs. In Section 5.1, we answer RQ1 and describe how the skills, attitudes, and knowledge of teaching professionals are distributed. In Section 5.2, we answer RQ2 and present the relations between the skills, attitudes, and knowledge of teaching professionals. In Section 5.3, we answer RQ3 and elaborate on the associations between personal and contextual factors and the skills, attitudes, and knowledge of teaching professionals.

### *5.1. Distribution of skills, attitudes, and knowledge of teaching professionals*

In this sub-section, we address how teaching the digital skills, attitudes towards digital technologies, and knowledge of digital technologies of teaching professionals are distributed. First, we present the distribution of the skills of teaching professionals (Cluster 1), measured in PIAAC using PS-in-TRE proficiency levels (Table 1). On the PIAAC test, 11% of the teaching professionals showed strong PS skills in a TRE, while 42% showed weak (or very weak) skills. We observed little difference when we compared the teaching professionals with respondents who had tertiary education but worked in a different industry. Of the latter, 12% showed strong skills and 44% showed weak skills. The respondents with less than tertiary education performed worse: only 4% showed strong skills, and no less than 72% showed weak skills. The percentages in Table 1 are survey weighted, with the *Observed n* column presenting the raw unweighted numbers of observations in the sample. Thus, the distribution in that column does not completely agree with the

**Table 1**
The distribution of proficiency levels among teaching professionals in the PIAAC PS in TRE sample.

| | Observed n | Weighted % |
|---|---|---|
| Weak skills (level 1 or below) | 1298 | 42 |
| Moderate skills (level 2) | 1062 | 47 |
| Strong skills (level 3) | 230 | 11 |
| Total | 2590 | 100 |

weighted percentages.

Of the 2590 respondents, 164 did not take the test. Because the test was available only in a digital environment, taking it required elementary computer skills. Of these 164 teaching professionals, 112 refused to use a computer in the testing session, and six reported having no computer experience. The rest failed the test of basic computer skills preliminary to the actual PS skills test. We assume that most of those who refused to take the test felt that their computer skills were insufficient. For the analyses, we merged the group that did not take the test with proficiency Levels 1 and below, as it is likely that these people (some 6% of the population of highly educated teaching professionals) had very weak computer skills.

Some subgroup percentages of weak and strong skills are presented in Table A1 in Appendix 2. There are subgroups, where the proportion of low performers is around 60% and the proportion of strong performers is also very low. For instance, the oldest age group seems to stand out from the rest, as well as those who do not use digital technologies much outside of work. Strong proficiency appears most frequently in the youngest age group.

We turn next to the attitudes of teaching professionals (Cluster 2). Descriptive percentages of the indicators of the attitudes in the TALIS data are presented in Table 2, both overall and in subgroups. Only a few remarkable differences were observed between the subgroups. Approximately half of the respondents reported that they let students use ICT always or frequently in class, demonstrating in practice their positive attitude towards ICT use. This percentage was highest among technology teachers (85%), while teachers of physical education represented the other extreme (28%). This finding is understandable given the subject matter in question. Slightly more than one-fourth of the respondents thought that investing in ICT was of high importance. Again, this proportion was highest among teachers of technology-related subjects. In PIAAC, the teaching professionals were asked whether they believed they had the computer skills needed to do their jobs well, and 89% claimed they did (Table A5 in Appendix 2). In comparison, the result among other tertiary-educated respondents was 93%.

Finally, Table 3 presents the percentages for the knowledge indicators of teaching professionals (Cluster 3). Overall, 60% of the respondents stated that the use of ICT in teaching was included in their formal education. However, large subgroup differences were observed. In the youngest age group, the percentage was 82%. The percentage was also high among technology teachers. The respondents in these two subgroups also felt more frequently than the others that they were well or very well prepared to use ICT in their teaching. The lowest related percentages were observed in the oldest age group and among those whose formal education was no higher than short-cycle tertiary education (Table 3). Correspondingly, most respondents in the oldest age group (57%) and among those with the lowest educational level (53%) recognised a need for professional development in the use of digital technologies. This percentage was also high among language teachers (53%). However, the actual rate of participation in professional development in ICT did not show much variation between the subgroups considered.

**Table 2**
Percentages of indicators of the attitudes of teaching professionals in the TALIS data.

| | Can support student learning through ICT a lot or quite a bit (%) | Lets students use ICT always or frequently (%) | Rates investing in ICT of high importance (%) |
|---|---|---|---|
| **Gender** | | | |
| Female | 67 | 47 | 30 |
| Male | 69 | 49 | 25 |
| **Age group** | | | |
| Below 30 | 71 | 41 | 26 |
| 30–49 | 69 | 48 | 29 |
| 50 or older | 62 | 50 | 28 |
| **Educational level** | | | |
| Short-cycle tertiary or below | 61 | 48 | 28 |
| Bachelor | 69 | 47 | 30 |
| Master or higher | 66 | 49 | 25 |
| **Subject category** | | | |
| Class teachers | 72 | 48 | 32 |
| Reading, writing, literature | 64 | 49 | 26 |
| Mathematics, science | 65 | 43 | 25 |
| Social studies, history, religion | 67 | 49 | 21 |
| Languages | 69 | 48 | 26 |
| Technology | 79 | 85 | 46 |
| Arts | 62 | 54 | 28 |
| Physical education | 50 | 28 | 24 |
| Other (incl. vocational skills) | 63 | 65 | 27 |
| **Total** | 68 | 48 | 28 |

**Table 3**
Percentages of indicators of knowledge and participation in professional development in ICT among teaching professionals in the TALIS data.

| | ICT included in formal education or training (%) | Felt well or very well prepared (%) | Moderate or high need for professional development in ICT (%) | Participated in professional development activities in ICT during the last year (%) |
|---|---|---|---|---|
| **Gender** | | | | |
| Female | 59 | 34 | 50 | 47 |
| Male | 62 | 45 | 43 | 52 |
| **Age group** | | | | |
| Below 30 | 82 | 55 | 37 | 46 |
| 30–49 | 65 | 39 | 47 | 47 |
| 50 or higher | 34 | 22 | 57 | 53 |
| **Educational level** | | | | |
| Short-cycle tertiary or below | 36 | 25 | 53 | 51 |
| Bachelor | 65 | 40 | 46 | 46 |
| Master or higher | 54 | 34 | 51 | 53 |
| **Subject category** | | | | |
| Class teachers | 63 | 35 | 50 | 48 |
| Reading, writing, literature | 53 | 35 | 51 | 48 |
| Mathematics, science | 63 | 42 | 44 | 50 |
| Social studies, history, religion | 55 | 36 | 47 | 51 |
| Languages | 49 | 32 | 53 | 54 |
| Technology | 77 | 73 | 21 | 46 |
| Arts | 53 | 36 | 46 | 44 |
| Physical education | 56 | 37 | 46 | 45 |
| Other (incl. vocational skills) | 52 | 44 | 50 | 51 |
| **Total** | 60 | 37 | 48 | 49 |

### 5.2. Relations between the skills, attitudes, and knowledge of teaching professionals

Regarding the second research question, a positive association was observed in the PIAAC data between the measured PS-in-TRE skills (Cluster 1) and attitudes (Cluster 2), represented by their perceived proficiency related to computer skills assumed to be needed at work. However, this association was not particularly strong: 84% of the teaching professionals with weak measured skills believed that they possessed the skills necessary for work (Table A4 in Appendix 2). Correspondingly, of those teaching professionals who believed they had the needed skills, 40% showed weak skills, 49% moderate skills, and only 12% showed strong skills when measured via the PIAAC test (Table A5 in Appendix 2). The Pearson correlation coefficient of these variables was 0.11. The value of the Cramér's V statistic was 0.12, also indicating a weak association.

Statistics measuring the associations of the TALIS items representing the attitudes (i.e., the ability to support student learning through the use of ICT, how often students are allowed to use ICT for projects or class work, and ratings of the importance of investing in ICT in education) and knowledge (i.e., the inclusion of ICT in the formal education or training of the respondent, self-assessed preparedness for using ICT for teaching, need for professional development in digital technology, and participation in ICT-related professional development) of teaching professionals are presented in Pearson correlation and the Cramér's V statistic are presented. Both statistical measures lead to similar conclusions. As mentioned earlier, most of the associations are weak, with some very close to zero, making it difficult to build adequate composite scores from the items. Therefore, the analysis was performed for single items only (see also, Section 6).

Regarding the indicators of attitudes, the only remarkable association was observed between the ability of respondents to support student learning via ICT and the frequency of allowing students to use ICT in class (Pearson correlation coefficient = 0.40, Cramér's V = 0.27). For the items representing knowledge, the inclusion of ICT in the formal education of teachers correlated strongly (Pearson correlation coefficient = 0.58, Cramér's V = 0.66) with the extent to which the respondent felt prepared for using ICT in teaching. The self-reported need for professional development in ICT had some association with other items: its correlation with the inclusion of ICT in formal education was −0.17, and its correlation with the extent to which the respondent felt prepared for using ICT in teaching was −0.28. The value of the Cramér's V statistic was 0.18 in both cases. Interestingly, there was a very limited association between the need for professional development and the actual participation in professional development activities.

The measures of attitudes did not correlate strongly with the measures of knowledge. The ability to support student learning via ICT had a weak positive association with feeling prepared for using ICT in teaching (Pearson's correlation = 0.21) and a weak negative association with the self-assessed need for professional development in ICT skills (Pearson's correlation = −0.19).

### 5.3. Associations between personal and contextual factors and the skills, attitudes, and knowledge of teaching professionals

To address the third research question, we conducted linear and logistic regression analyses examining the personal and contextual factors associated with variables indicating the skills (Cluster 1), attitudes (Cluster 2), and knowledge (Cluster 3) of teaching professionals.

Regarding skills, we fitted separate binary logistic regression models for weak skills and strong skills, with moderate skills serving as the reference group. We first fitted models containing the nine background variables described above as explanatory factors. Several explanatory variables did not show statistical significance and were removed from the final models. A summary of the final models (regression coefficients *b*, standard errors *s.e.,* and odds ratios *OR*) presenting only the significant variables is presented in Table 4. For the non-significant variables, the cells in the table are left empty. The possible between-country differences were controlled for in all models. The differences were statistically significant in weak skills, but not in strong skills. Because the country effects were not the focus of this analysis, they are not presented in Table 4.

According to these results, age plays a central role in the models. It was the only independent variable which appeared statistically significant for both weak skills and strong skills; higher age increased the probability of possessing weak skills and decreased the probability of possessing strong skills (Table 4). The other independent variables did not systematically show significant associations with skills when the other variables—age in particular—were controlled. No statistically significant association was found between gender and possessing weak or strong PS-in-TRE skills.

From Table 4, it can also be seen that the probability of having weak skills was significantly greater for non-native speakers of the testing language. However, regarding strong measured skills or self-assessed skills no such association was found. The number of books at the respondent's home (often used as an indicator for socio-economic status) decreased the probability of weak skills but had no association with strong skills. Strong skills were more typical the higher the formal degree the respondent possessed. The frequency of ICT use at work decreased the probability of weak skills, but there was no association with strong skills. This suggests that using digital technologies at work may guard against weak performance but does not guarantee strong proficiency. It is worth noting that the Nagelkerke R-squared measures of the fitted models were rather low, suggesting that there is much unexplained variation between individuals (Table 4). The R-squared (0.13) was somewhat higher with the probability of weak skills. Finally, we note that the variables related to the attitudes of the respondents towards learning and possible teacher education were missing in the models. Thus, it did not matter whether the respondents had majored in education or another subject, when adjusted for the other variables.

Table 4 also contains results of the logistic regression analysis for a PIAAC variable indicating the beliefs of the respondents regarding sufficient skills needed at work, representing the attitudes of teaching professionals (Cluster 2). We notice that according to the PIAAC data, there were three significant explanatory variables (age, gender, and frequency of ICT use outside of work) for the probability that a respondent believes he/she possesses the computer skills needed at work. The probability was highest among the youngest respondents, males, and the most active ICT users.

The results of the linear regression analyses for the TALIS variables representing attitudes (Cluster 2) are presented in Table 5. In these analyses, we use age, gender, level of formal education, and subject category as independent variables, while country effects were controlled. Again, only statistically significant variables were retained in the models; the cells for non-significant variables in the table are left empty. In Table 5, *beta* denotes the standardised regression coefficient. For the polytomous independent variables (formal education and subject taught), the last category was used as the reference group.

The explanatory power of the regression models, measured using R-squared, was low, suggesting small subgroup differences (Table 5). It is typical of large data sets that even small effects tend to become statistically significant. Of the considered independent variables, the subject category showed a statistically significant association with each dependent variable. The technology teachers can support their students more and let them use ICT the most, while the opposite tendency was observed among teachers of physical education. The technology teachers also rated investing in ICT as important. These findings are hardly surprising. The teaching professionals with formal education of ISCED 6 or lower tended to rate investing in ICT as more important than those with higher education, but there was no significant association between the other two dependent variables and formal education. The age and gender of the teaching professionals were not associated with how often

**Table 4**
Logistic regression models for teaching professionals' weak and strong skills in PIAAC data and self-assessed possession of the computer skills needed at work, controlled for country.

| | Weak skills | | | Strong Skills | | | Believes to possess the computer skills needed at work | | |
|---|---|---|---|---|---|---|---|---|---|
| | n = 2265 | | | n = 1292 | | | n = 2462 | | |
| | R-squared = 0.13 | | | R-squared = 0.04 | | | R-squared = 0.06 | | |
| | *b* | *s.e.* | *OR* | *b* | *s.e.* | *OR* | *b* | *s.e.* | *OR* |
| Age | 0.45[a] | 0.10 | 1.57 | −0.40** | 0.13 | 0.67 | −0.30** | 0.09 | 0.74 |
| Gender (male) | | | | | | | 0.83[a] | 0.22 | 2.30 |
| Speaks native language | −0.80* | 0.34 | 0.45 | | | | | | |
| Level of formal education | | | | 0.59** | 0.21 | 1.80 | | | |
| Number of books at home | −0.22** | 0.08 | 0.80 | | | | | | |
| ICT use at work | −0.50* | 0.20 | 0.61 | | | | | | |
| ICT use outside work | | | | | | | 0.33* | 0.15 | 1.40 |

[a] ***p<0.001; **p < 0.01; *p < 0.05.

**Table 5**
Linear regression models for items of teaching professionals' attitudes in ICT in TALIS data, controlled for country.

| | Ability to support student learning through the use of ICT | | | How often let students use ICT | | | Importance of investing in ICT in education | | |
|---|---|---|---|---|---|---|---|---|---|
| | n = 48,189 | | | n = 38,042 | | | n = 47,570 | | |
| | R-squared = 0.02 | | | R-squared = 0.03 | | | R-squared = 0.02 | | |
| | *b* | *s.e.* | *beta* | *b* | *s.e.* | *beta* | *b* | *s.e.* | *beta* |
| **Demographic factors** | | | | | | | | | |
| Age | −0.06[a] | 0.01 | −0.09 | | | | 0.02[a] | <0.01 | 0.04 |
| Gender (male) | −0.04* | 0.02 | −0.02 | | | | −0.08[a] | 0.01 | −0.05 |
| **Formal education** | | | | | | | | | |
| ISCED 5 or below | | | | | | | 0.06** | 0.02 | 0.02 |
| ISCED 6 | | | | | | | 0.05** | 0.02 | 0.03 |
| ISCED 7 or higher | | | | | | | <ref> | | |
| **Subject category** | | | | | | | | | |
| Class teachers | 0.11[a] | 0.03 | 0.06 | −0.23[a] | 0.04 | −0.13 | 0.09[a] | 0.02 | 0.07 |
| Reading, writing, literature | | | | −0.10** | 0.04 | −0.04 | −0.04* | 0.02 | −0.02 |
| Mathematics, science | 0.04* | 0.02 | 0.02 | −0.25[a] | 0.04 | −0.11 | −0.05* | 0.02 | −0.03 |
| Social studies, history, religion | | | | −0.17[a] | 0.04 | −0.05 | −0.12[a] | 0.02 | −0.05 |
| Languages | 0.11[a] | 0.02 | 0.03 | −0.17[a] | 0.04 | −0.05 | −0.07** | 0.02 | −0.02 |
| Technology | 0.38[a] | 0.07 | 0.04 | 0.78[a] | 0.08 | 0.09 | 0.29[a] | 0.06 | 0.04 |
| Arts | | | | | | | | | |
| Physical education | −0.38[a] | 0.04 | −0.08 | −0.71[a] | 0.06 | −0.14 | | | |
| Other (incl. vocational skills) | <ref> | | | <ref> | | | <ref> | | |

[a] ***p<0.001; **p < 0.01; *p < 0.05.

he/she allowed students to use ICT in class. Instead, the older the teaching professional, the less capable he/she felt of being able to support student learning through ICT, and the higher he/she rated the importance of investing in ICT. With the other variables controlled, the female teaching professionals, on average, felt slightly more competent than men in supporting student learning through ICT. Furthermore, it was more typical of females than males to rate investing in ICT as important.

The modelling results for the TALIS indicators of the knowledge of teaching professionals (Cluster 3) are presented in Table 6. We conducted a logistic regression analysis for the inclusion of ICT in formal education or training and participation in ICT-related professional development activities. The other two variables—the extent to which the respondent felt prepared for using ICT in teaching and the extent to which the respondent felt a need for professional development in ICT skills—were analysed using linear regression. Of the four models, the models dealing with the inclusion of ICT in the formal education of the respondent and the perceived preparedness of the respondent for using ICT in teaching showed reasonable explanatory power. The Nagelkerke R-squared for the former was 0.13, and R-squared for the latter was 0.11.

In the models for inclusion of ICT in the formal education of the respondent, the perceived preparedness of the respondent for using ICT in teaching, and the need for professional development, the independent variables behaved in a fairly coherent manner (Table 6). The model for actual participation in professional development was slightly different. One reason for this could be the small differences between the teacher subgroups (see Table 3). The relations between age and the dependent variables were particularly consistent. The older the respondent, the less often he/she had the use of ICT for teaching included in his/her formal education, the less prepared he/she felt for using ICT in teaching, and the more need he/she felt for ICT-related professional development. This suggests that the average level of knowledge decreases with the age of the respondent. However, age played no significant role when actual participation in professional development was considered.

According to the results in Table 6, a high level of knowledge was often recorded among males and teachers of technology, while the opposite was observed in several other teacher groups. Notably, class teachers and teachers of physical education often felt less prepared to use ICT in their teaching (with other variables controlled). In addition, class teachers indicated a stronger need for professional development in ICT skills than other teacher groups. Male teachers indicated less need for ICT-related professional development than females but participated more actively in ICT-related professional development activity. The technology teachers indicated the least need for professional

**Table 6**
Regression models for items of teaching professionals' ICT knowledge in TALIS data, controlled for country.

| | ICT included in formal education | | | Feeling prepared for using ICT in teaching | | | Need for professional development in ICT skills | | | Participation in professional development activities in ICT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n = 48,970 | | | n = 46,970 | | | n = 48,453 | | | n = 46,804 | | |
| | R-squared = 0.13 | | | R-squared = 0.11 | | | R-squared = 0.03 | | | R-squared = 0.01 | | |
| | (Nagelkerke) | | | | | | | | | (Nagelkerke) | | |
| | *b* | *s.e.* | *OR* | *b* | *s.e.* | *OR* | *b* | *s.e.* | *beta* | *b* | *s.e.* | *OR* |
| **Demographic factors** | | | | | | | | | | | | |
| Age | −0.64[a] | 0.02 | 0.53 | −0.23[a] | 0.01 | −0.30 | 0.09[a] | 0.01 | 0.12 | | | |
| Gender (male) | 0.30[a] | 0.04 | 1.36 | 0.20[a] | 0.02 | 0.09 | −0.12[a] | 0.02 | -.06 | 0.19[a] | 0.04 | 1.20 |
| **Formal education** | | | | | | | | | | | | |
| ISCED 5 or below | −0.35[a] | 0.08 | 0.71 | −0.09[a] | 0.03 | −0.02 | | | | | | |
| ISCED 6 | | | | | | | | | | | | |
| ISCED 7 or higher | <ref> | | | <ref> | | | | | | | | |
| **Subject category** | | | | | | | | | | | | |
| Class teachers | −0.18** | 0.06 | 0.84 | −0.24[a] | 0.02 | −0.13 | 0.24[a] | 0.03 | 0.13 | 0.23** | 0.07 | 1.26 |
| Reading, writing, literature | −0.44[a] | 0.06 | 0.64 | −0.18[a] | 0.02 | −0.06 | 0.12[a] | 0.02 | 0.04 | 0.19* | 0.07 | 1.21 |
| Mathematics, science | | | | | | | | | | 0.22[a] | 0.06 | 1.25 |
| Social studies, history, religion | −0.32[a] | 0.06 | 0.72 | −0.14[a] | 0.02 | −0.04 | 0.08[a] | 0.02 | 0.02 | 0.22** | 0.07 | 1.25 |
| Languages | −0.41[a] | 0.06 | 0.67 | −0.14[a] | 0.03 | −0.03 | 0.09[a] | 0.03 | 0.02 | 0.33[a] | 0.07 | 1.39 |
| Technology | 0.40* | 0.20 | 1.48 | 0.52[a] | 0.08 | 0.05 | −0.45[a] | 0.08 | −0.05 | | | |
| Arts | −0.43[a] | 0.09 | 0.65 | −0.14[a] | 0.04 | −0.03 | | | | | | |
| Physical education | −0.73[a] | 0.10 | 0.48 | −0.27[a] | 0.04 | −0.05 | 0.14** | 0.04 | 0.03 | | | |
| Other (incl. vocational skills) | <ref> | | | <ref> | | | <ref> | | | <ref> | | |

[a] ***p<0.001; **p < 0.01; *p < 0.05.

development activities.

Regarding formal education, those with short-term tertiary education as their highest level of education demonstrated a slightly lower average knowledge than the other groups in terms of having ICT included in their education and feeling less prepared for using ICT in teaching.

We noted earlier (Section 5.2) that the measured computer skills did not necessarily match the perception of having the skills needed for work (Table A4 and Table A5 in Appendix 2). We therefore looked more closely at three subgroups of interest: those who showed weak skills and believed that they lacked the needed skills (n = 224), those who showed weak skills but believed that they had the needed skills (n = 1051), and those who showed strong skills and believed they had the needed skills (n = 220). Table A2 in Appendix 2 presents a comparison of the percentage distributions of the personal and contextual factors in these three subgroups. These distributions illustrate how the subgroups differ in composition. The differences reflect the role of personal and contextual factors in explaining the mismatch between measured skills and attitudes.

First, we noticed that the group of respondents who had strong skills and believed they had sufficient skills for work differed from the other two groups in several ways (Table A2 in Appendix 2). Half of the teaching professionals in this group were less than 35 years old, and almost 80% of them had a master's degree or higher. They also were more active ICT users both at work (52%) and outside of work (73%). There were almost equal numbers of females and males in the strong-performing group, while females were in the majority in the other groups (Table A2 in Appendix 2). The two weak-performing groups had only a few remarkable differences. The weak-performing teaching professionals who nevertheless believed that they had the skills needed at work were, on average, younger than those who believed that their skills were insufficient. In addition, more males believed in their skills than females (30% versus 15%).

## 6. Discussion

It has been argued that technological advancement in society is radically transforming the entire landscape of learning (Harrison & Hutton, 2014), and it is generally agreed that education plays an important role in equipping students with digital competences (Hämäläinen et al., 2019). For example, Darling-Hammond et al. (2017) argue that novel ways of teaching are needed to develop 21st-century student competences. Most studies focusing on how teaching professionals prepare students for the future and how they develop their own digital competences (i.e., skills, attitudes, and knowledge related to digital technologies) have been small-scale, empirical case studies or large-scale studies using self-reports. The lack of large-scale research based on cognitive assessments of the digital competences of teaching professionals is surprising, given that teaching professionals are a critical factor in students' learning. Therefore, large-scale data sets provide appealing possibilities for research. However, along with these optimistic notions, we must critically consider that large-scale data may be more difficult to utilise in empirical research than it may seem at first sight. This study tackled this issue and explored the possibilities and limitations of applying the PIAAC and TALIS data to develop a deeper understanding of the digital competences of teaching professionals. Our aim was to investigate the variation and relations between measured and self-reported factors associated with the digital competence (skills, attitudes, and knowledge) of teaching professionals (Fig. 1) based on two international large-scale surveys. Through the theoretical lens of digital competence, we explored the relationships between the skills, attitudes, and knowledge related to digital technologies of European teaching professionals in light of these data and identified the personal and contextual factors related to them.

According to the TALIS data, it seems that teacher education institutions have paid attention to enhancing the digital competences of future teaching professionals (Section 2.3). More than 80% of the respondents in the youngest age group had familiarised themselves with the use of digital technologies for teaching as part of their formal education, and they also believed that they were well or very well prepared to use digital technologies in teaching. By contrast, the oldest age group and those with the lowest level of formal education clearly recognised a need for professional development in digital competences. These findings are supported by the PIAAC data, which reports older teaching professionals having weak digital skills (Section 2.1) and experiencing that they lacked the skills needed at work (Section 2.2), compared to younger teaching professionals.

Even though the TALIS data suggest that approximately two-thirds of teaching professionals claimed to be able to support student learning through digital technology, two out of five showed weak skills in the

PIAAC test. Interestingly, our analysis shows that the level of the measured digital skills of the teaching professionals (Section 2.1) might differ from the level of skills they experience is adequate for their work (Section 2.2). Our analysis of the PIAAC data outlined three groups: those who experienced that their digital skills were adequate and whose PS-in-TRE tests demonstrated advanced skills, those who experienced that their skills were adequate but exhibited low skills, and those who indicated a need to enhance their skills, which was also reflected in the PS-in-TRE test. Our analysis of the TALIS data indicates that some teaching professionals (e.g., physical education teachers) experienced that digital skills were not vital to their work; thus, their self-reports may have reflected their experiences that a lower skill level was adequate. Similar results were seen in the ICILS, where some teachers, e.g., science teachers, emphasised digital skills more in their teaching than some other teachers, e.g., physical education teachers (Fraillon et al., 2019). However, the rapid digitalisation of society is changing learning demands, and the Covid-19 pandemic has highlighted the need for all teaching professionals to be able to use diverse digital technologies. This notion is also supported by the Framework for the Digital Competence of Educators (DigCompEdu; Redecker, 2017), which suggests that developing personal digital competences as part of professional and pedagogic competences, and facilitating the digital competences of learners, is fundamental for teaching professionals at all levels of education.

The digital competence of teaching professionals is formed via several important factors. Instead of focusing on the external barriers—also known as first-order barriers—such as a lack of resources or institutional/collegial support (Vähäsantanen & Hämäläinen, 2019) that hinder the use of technological tools and facilitation of the digital competences of learners (Alarcón, del Pilar Jiménez, & de Vicente-Yagüe, 2020; Hatlevik & Hatlevik, 2018), Ertmer et al. (2012) suggest that paying more attention to internal barriers—second-order barriers: skills, attitudes, and knowledge—may facilitate a digital transformation. Nelson and Hawk (2020) indicate that the beliefs of pre-service teachers regarding the utility and importance of technology may predict their ambition to shape the digital transformation of schools. The use of multiple strategies can overcome internal (second-order) barriers, such as attitudes, which is crucial to modifying intentions and behaviours related to technology integration (Nelson et al., 2019; Sánchez-Prieto et al., 2019; Tondeur et al., 2018). Tondeur et al. (2018) discovered that the *ease of use*, attitudes of the teaching professional towards digital technologies in education, and the strategies employed by teacher education institutions all have a positive association with self-perceived competence.

When considering the findings of this study, some limitations should be considered. First, the three factors of digital competence were examined via two separate data sets collected from different participants and at different times. Thus, it is not possible to directly relate the results on skills to those on attitudes and knowledge. Secondly, in PIAAC, the measure of PS-in-TRE focuses on skills that are not specific to the teaching profession. Instead, it focuses on what Starkey (2020) calls *generic digital competence*, meaning skills that are useful to anyone for managing work or everyday life in the 21st century. Consequently, they can also be applied in the teaching profession. Third, it is crucial to keep in mind that the data and the items in existing large-scale surveys do not squarely match the theoretical concept of digital competence (Section 2). Even though our results suggest that the PIAAC data captured the level of skill of the teaching professionals adequately, approaching the knowledge and attitudes of teachers via the TALIS data proved to be more problematic. The main problem was that the intercorrelations of the items (Appendix 3) appeared, in many cases, to be too low for constructing valid and reliable composite scores for measuring attitudes and knowledge. Attitudes towards students' use of ICT in class were not associated with the value placed on the importance of investing in ICT in education. Surprisingly, the correlations of participation in ICT-related professional development with the respondent's background in ICT and self-assessed digital competence (measured via inclusion of ICT in teacher education and training, and self-assessed preparedness for using ICT for teaching and need for professional development in ICT) were practically zero. It was thus advisable to perform TALIS data analyses with single-item measures only. From a theoretical perspective, however, the items selected from the TALIS data implicitly fit the upper concept of attitudes relatively well. Both self-efficacy and technology usage can be regarded as indicators of (positive) attitudes to the use of digital technologies in teaching (Section 2.2) although it is apparently a two-way relationship (Yeşilyurt et al., 2016; Celik & Yeşilyurt, 2013). Furthermore, even though the TALIS items measuring knowledge focused to a large extent on the institutional support received by teaching professionals from their schools and teacher education institutions, we argue that this support plays a fundamental role in the development of the knowledge of digital technologies possessed by teaching professionals (Tondeur et al., 2018), and is thus a legitimate source of such information (Section 2.3). In addition, as technologies are evolving at a rapid pace, there are unfortunately no up-to-date large-scale instruments to measure knowledge on digital technologies. As a final limitation, we explicitly differentiate the digital competences of teaching professionals from general professional competence, which was never the focus of this study.

Despite these limitations, our study has clear advantages. First, even though the existing studies have differences concerning the operationalisation of factors associated with digital competence, e.g., dependence on contextual factors affecting teaching professionals, such as whether they teach physics or physical education (Koehler et al., 2012), a common feature is that these studies are frequently based on self-reports by teaching professionals (cf. most measurements of digital skills concentrate on students). Self-reports are also easy to administer to large sample sizes, and their results correlate with the quality of technology-enhanced instruction (Scherer et al., 2017). However, it can be argued that self-reports do not actually measure the skills of teaching professionals in practice (Akyuz, 2018) but only their self-reported attitudes and knowledge. Relying only on self-reports is thus problematic, as the personal factors affecting teaching professionals may play a role in their self-reports. For example, male teaching professionals seemed to experience superior knowledge of digital technologies (TALIS) and experience more often than female teaching professionals that they possessed the digital skills needed at work (PIAAC). Still, the measured skills did not differ between male and female teaching professionals (Fig. 1, RQ3). Thus, our study addresses one of the major challenges in digital competence research: the reliance on self-reports alone (Starkey, 2020). Second, the parallel analysis of PIAAC and TALIS still sheds light on the variation and relations between the factors associated with the digital competence of teaching professionals (Section 2, Fig. 1, and RQs 1–2), even though our study shows that large-scale surveys cannot be squarely used to measure these factors. Despite the previously discussed weaknesses of the adopted items from the TALIS data for measuring attitudes and knowledge, our findings suggest weak associations between (i) the measured digital skills of teaching professionals and their self-reported attitudes concerning whether they possess the digital skills needed to do their jobs well (PIAAC), and (ii) knowledge of digital technologies and their attitudes towards these technologies (TALIS). These findings indicate that equal attention should be paid to all three factors associated with the digital competence of teaching professionals (Fig. 1) to enable them to shape digital transformation in schools and develop their educational practices in the emerging technological landscape.

## 7. Conclusion

In our evolving society, the work of teaching professionals has diversified, and their pedagogical role has changed (Häkkinen & Hämäläinen, 2012). An important outcome of this study is a deeper understanding, based on large-scale assessment data, of digital transformation from the perspective of teaching professionals. Our results indicate that individual measured (objective) and experienced (subjective) digital skills may differ among teaching professionals. In the future, a clearer answer is needed to the fundamental question of how the skills, attitudes, and knowledge of teaching professionals intertwine with their teaching. Thus far, it is understood that teaching professionals generally hold positive attitudes towards the use of digital technologies in teaching and in the broader society, and that they feel confident of their own skills (Fraillon et al., 2019). Despite this positive attitude, there is a significant variance in the skills of teaching professionals (Hämäläinen et al., 2019) as well as variation between and within countries in the degree to which teaching professionals use digital technologies in their work (Fraillon et al., 2019; OECD, 2020). Based on measured outcomes, two out of five teaching professionals have weak or very weak skills. Education today and in the future depends on the development of work communities in which diverse competences complement each other and the skills, attitudes, and knowledge of teaching professionals can be enhanced by professional development. Increasing the use of digital technologies in pedagogical practices should provide teaching professionals with recurring opportunities to develop their skills. Equally important is encouraging teaching professionals to try new practices using digital technologies, developing new methods of assessing skills, and creating an accepting atmosphere in which learning is appreciated (Lawless & Pellegrino, 2007; Seufert et al., 2019).

## CRediT roles

This study was grounded on close collaboration between all the authors. The first author was responsible for the coherent whole, and the second author was responsible for the analysis. However, all the following authors had significant contributions on writing.

## Declaration of interest statement

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2020.106672.

## Appendix 1. The seven TALIS Teacher Questionnaire items selected for our analyses

The items specified to indicate teaching professionals' attitudes:

- In your teaching, to what extent can you support student learning through the use of digital technology? (question 34 m)
- How often do you let students use ICT for projects or class work? (question 42p)
- Thinking about education as a whole, if the budget were to be increased by 5%, how would you rate the importance of investing in ICT? (question 55a)

The items specified to indicate teaching professionals' knowledge:

- Was the use of ICT for teaching included in your formal education or training? (question 6 h part A)
- To what extent did you feel prepared for using ICT for teaching? (question 6 h part B)
- Were ICT skills for teaching included in your professional development activities during the last 12 months? (question 23e)
- To what extent do you currently need professional development in ICT skills for teaching? (question 27e)

## Appendix 2. Percentage tables

**Table A1**
Percentages of weak and strong skills, and of those who think they have computer skills needed at work, in selected subgroups of teaching professionals in PIAAC data

| | Weak PS in TRE skills | Strong PS in TRE skills | Thinks to have computer skills needed to do job well |
|---|---|---|---|
| Age below 25 years | 17 | 23 | 99 |
| Age 25–34 years | 28 | 18 | 93 |
| Age 35–44 years | 37 | 12 | 88 |
| Age 45–54 years | 48 | 7 | 87 |
| Age 55 years or more | 65 | 3 | 83 |
| Male | 37 | 15 | 93 |
| Female | 45 | 8 | 86 |
| Native speaker of test language | 41 | 11 | 91 |
| Non-native speaker of test language | 56 | 10 | 88 |
| Formal education: short-cycle tertiary or below | 59 | 4 | 85 |
| Formal education: bachelor | 46 | 9 | 89 |
| Formal education: master or higher | 37 | 13 | 90 |
| 0-25 books at home | 62 | 3 | 90 |

(continued on next page)

**Table A1** (*continued*)

| | Weak PS in TRE skills | Strong PS in TRE skills | Thinks to have computer skills needed to do job well |
|---|---|---|---|
| 26-100 books at home | 48 | 9 | 86 |
| 101-200 books at home | 43 | 11 | 89 |
| 201-500 books at home | 40 | 12 | 88 |
| Over 500 books at home | 27 | 15 | 92 |
| ICT use at work low | 61 | 10 | 90 |
| ICT use at work moderate | 47 | 8 | 88 |
| ICT use at work high | 32 | 15 | 90 |
| ICT use outside work low | 68 | 3 | 81 |
| ICT use outside work moderate | 48 | 8 | 87 |
| ICT use outside work high | 35 | 14 | 91 |

**Table A2**
Percentage distributions of personal and contextual background variables in three teaching professionals' subgroups of interest in PIAAC data

| | Weak PS in TRE skills, does not believe to possess computer skills needed at work n = 224 | Weak PS in TRE skills, believes to possess computer skills needed at work n = 1051 | Strong PS in TRE skills, believes to possess computer skills needed at work n = 220 |
|---|---|---|---|
| Age below 25 years | 0 | 1 | 5 |
| Age 25–34 years | 10 | 20 | 44 |
| Age 35–44 years | 18 | 25 | 27 |
| Age 45–54 years | 32 | 29 | 19 |
| Age 55 years or more | 39 | 24 | 5 |
| **Total** | **100** | **100** | **100** |
| Male | 15 | 30 | 45 |
| Female | 85 | 70 | 55 |
| **Total** | **100** | **100** | **100** |
| Native speaker of test language | 6 | 11 | 6 |
| Non-native speaker of test language | 94 | 89 | 94 |
| **Total** | **100** | **100** | **100** |
| Formal education: short-cycle tertiary or below | 27 | 21 | 5 |
| Formal education: bachelor | 23 | 23 | 16 |
| Formal education: master or higher | 50 | 56 | 79 |
| **Total** | **100** | **100** | **100** |
| 0-25 books at home | 9 | 14 | 2 |
| 26-100 books at home | 32 | 29 | 27 |
| 101-200 books at home | 21 | 20 | 21 |
| 201-500 books at home | 27 | 25 | 24 |
| Over 500 books at home | 11 | 12 | 25 |
| **Total** | **100** | **100** | **100** |
| ICT use at work low | 4 | 7 | 6 |
| ICT use at work moderate | 63 | 64 | 42 |
| ICT use at work high | 33 | 29 | 52 |
| **Total** | **100** | **100** | **100** |
| ICT use outside work low | 16 | 10 | 3 |
| ICT use outside work moderate | 40 | 42 | 24 |
| ICT use outside work high | 45 | 47 | 73 |
| **Total** | **100** | **100** | **100** |

**Table A3**
Numbers of observations in background variable categories used in analyses of TALIS data

| Gender | n |
|---|---|
| Females | 35,819 |
| Males | 14,979 |
| **Age group** | |
| Below 30 | 6404 |
| 30-49 | 27,518 |
| 50 or higher | 16,832 |
| **Educational level** | |
| Short-cycle tertiary or below | 4054 |
| Bachelor | 23,161 |

(*continued on next page*)

**Table A3** (*continued*)

| Gender | n |
|---|---|
| Master or higher | 23,455 |
| **Subject category** | |
| Class teachers | 11,171 |
| Reading, writing, literature | 7879 |
| Mathematics, science | 13,289 |
| Social studies, history, religion | 6172 |
| Languages | 4728 |
| Technology | 558 |
| Arts | 2192 |
| Physical education | 1675 |
| Other (incl. vocational skills) | 2536 |
| **Total n** | 50,800 |

**Table A4**
Percentages of teaching professionals in PIAAC data who believed they possessed the computer skills needed at work, in the three skills subgroups

| Believes to possess computer skills needed at work | Weak skills % | Moderate skills % | Strong skills % | All respondents |
|---|---|---|---|---|
| Yes | 84 | 91 | 94 | 89 |
| No | 16 | 9 | 6 | 11 |
| Total | 100 | 100 | 100 | 100 |

**Table A5**
Distribution of teaching professionals' skills in the PIAAC subgroups of self-assessed computer skills needed at work

| Believes to possess computer skills needed at work | Weak skills % | Moderate skills % | Strong skills % | Total |
|---|---|---|---|---|
| Yes | 40 | 49 | 12 | 100 |
| No | 58 | 36 | 6 | 100 |
| All respondents | 42 | 47 | 11 | 100 |

## Appendix 3. Associations of TALIS items serving as indicators of teaching professionals' attitudes and knowledge

**Table A6**
Pearson correlations (lower triangle) and Cramér's V statistics (upper triangle) measuring associations of the TALIS indicators of teaching professionals' attitudes and knowledge

| | Can support student learning through the use of ICT | How often let students use ICT | Rates investing in ICT in education important | ICT included in formal education | Feeling prepared for using ICT in teaching | Need for professional development in ICT skills | Participated in professional development activities in ICT |
|---|---|---|---|---|---|---|---|
| Can support student learning through the use of ICT | 1 | 0.27 | 0.06 | 0.12 | 0.14 | 0.14 | 0.15 |
| How often let students use ICT | 0.40 | 1 | 0.06 | 0.07 | 0.09 | 0.05 | 0.17 |
| Rates investing in ICT in education important | 0.08 | 0.07 | 1 | 0.02 | 0.03 | 0.11 | 0.07 |
| ICT included in formal education | 0.12 | 0.03 | 0.02 | 1 | 0.66 | 0.18 | 0.00 |
| Feeling prepared for using ICT in teaching | 0.21 | 0.12 | −0.01 | 0.58 | 1 | 0.18 | 0.06 |
| Need for professional development in ICT skills | −0.19 | −0.04 | 0.13 | −0.17 | −0.28 | 1 | 0.09 |
| Participated in professional development activities in ICT | 0.15 | 0.17 | 0.07 | 0.00 | 0.05 | 0.08 | 1 |

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