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How digitalised are vocational teachers? Assessing digital competence in vocational education and looking at its underlying factors

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ABSTRACT

Teachers' digital competence (TDC) is an important condition for the effective integration of technologies in education, and it depends on personal and context-related factors. Different frameworks and instruments have been developed to measure TDC. However, research on digital competence in vocational education and training (VET) is still scarce. Therefore, this study aims: (a) to provide a snapshot of the status quo of digital competence on a sample of 1692 Swiss VET teachers, both using an assessment instrument that relies on previous validated questionnaires, and at the same time accounting for VET-related specificities; (b) to examine possible differences in digital competence depending on the VET teachers' profiles (i.e. professional baccalaureate, professional subject and general education teachers); and (c) to investigate whether personal and context-related factors play a similar role in VET like in other educational settings. The results confirm the validity of the 10-dimensional structure of the TDC assessment instrument. Compared with previous results in other educational domains, our findings indicate that VET teachers place themselves at a similar degree of digital competence, with a few differences across profiles in some of the sub-competences. Moreover, multiple regression analysis highlights the main role of attitude towards technology and digital tool use frequency among the personal factors that contribute to TDC development. The teachers' workload, rarely considered in previous studies, is also a relevant factor. For the context-related factors, curriculum support is the element with the largest effect on TDC, although it has a smaller impact than the personal factors.

1. Introduction

Digitalisation has strongly reappeared as a central focus of education policy in the last few years. This is especially true for vocational education and training (VET), a sector that has always focussed on supporting both of its intertwined and inseparable components, economy and education.

Although some pioneering studies predicted alarming effects of digitalisation in the job market (Bührer & Hagist, 2017; Frey & Osborne, 2013) and the so-called fourth industrial revolution (e.g., Brynjolfsson & McAfee, 2014), these effects have largely failed to surface. Instead, a clearer view of a positive new configuration of the complementary interplay between humans and machines has

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emerged (Aepli et al., 2017; Pfeiffer, 2018). Digitalisation has become an opportunity, a positive challenge for maintaining economic advantages and competitiveness.

The economy-centred debate has also contributed to raising political awareness on the important role of education, and in particular of vocational education. Indeed, vocational education constitutes one of the framework requirement for an effective digital economy. This is evident in some policy papers concerning Switzerland, a country with one of the most evolved VET systems (Bonoli et al., 2018; Organisation for Economic Co-operation and Development [; OECD], 2009). Covering two-thirds of the students in upper secondary schools, the Swiss VET system is organized on the alternance between a school-based and a work-based track. Apprentices work in a company for three-to-four days per week, tutored by an in-company trainer, and attend the vocational school – where VET teachers are educating them – for the rest of the week. A third learning location – so-called branch courses, organized by inter-company trainers – is also foreseen, often directly managed by the corporate associations to assure the training plan is homogeneous all over the country.

In 2017, two reports by the Swiss federal government highlighted the important contribution of vocational training to the challenges raised by digital transformation through the training of the general public and employees (Swiss Confederation, 2017a; 2017b). A specific programme to further develop the VET system appeared in 2018 (see Swiss Confederation, 2018, and https://berufsbildung2030.ch/de/).

Preparing the system to face the digital transformation requires developing the digital competence of the citizens (Carretero et al., 2017; Swiss Confederation, 2019) and of the active professionals. In the case of schools, the focus is on the teachers' digital competence. This is not a new issue. While during the 1980s the effective integration of technology in education focused on the availability of and access to the technological infrastructure, in the 1990s, the focus shifted to the relevance of the teachers' professional development (Ottestad & Gudmundsdottir, 2018). Since then, additional considerations about environmental and contextual factors have emerged, but the digital competence of teachers remains a key factor in international educational policies to date (e.g., OECD, 2019).

Several conceptual frameworks have been developed to comprehensively clarify what digital competence includes, and various corresponding measurement instruments have been developed. Some self-assessment instruments on digital competence for teachers and school leaders exist (Caena & Redecker, 2019; Ghomi & Redecker, 2019). However, most of these instruments focus on pre-service teachers (McGarr & McDonagh, 2019), and even the most recent contributions point to the need to investigate other educational contexts than primary and lower secondary education (Lucas et al., 2021). To the best of our knowledge, there is no updated picture of the digital competence of vocational education in-service teachers. This specific context implies the need to consider the particularities of the VET system, where the use of technology is crucial for the connectivity between the VET learning locations, i.e. for better articulating the school- and the work-based tracks (Cattaneo, Gurtner, & Felder, 2021; Kilbrink et al., 2020), and where different teacher profiles could also react to the need to develop digital competence in different ways. This gap also marks the need to assess the effects of personal characteristics (e.g. age, gender, attitude towards technology use) and contextual factors (e.g. availability of infrastructures, support of school management) in the development of the VET teachers' digital competence (TDC) compared to other contexts.

This study aims to fill the gaps in the research on the vocational education system, by proposing and testing a measurement tool based on DigCompEdu while integrating VET-specific items. This was accomplished through a voluntary self-administered online survey with 1692 teachers at Swiss VET schools. Moreover, the influences of the teacher profiles and personal and contextual factors on VET-specific digital competence were considered. We used confirmatory factor analysis to validate the instrument. Then, simple and multiple linear regressions were applied to evaluate the effect of all the personal and context-related factors on TDC, as well as to investigate their reciprocal interrelation. Analysis of variance was used to compare different vocational teaching profiles.

In the following section, we introduce the concept of TDC in the literature and its existing assessment instrument (2.1), we summarize the role of personal and contextual factors in TDC (2.2.), and the TDC-specific traits in the VET context (2.3). Then, we present the study design (section 3), the results (section 4) and discuss the implications for research and practice (section 5).

2. Frameworks and factors affecting teachers' digital competence and VET teachers' profiles

In this section we define the concept of TDC in the relevant literature, by introducing some established frameworks for TDC, and by distinguishing between the theory-driven and the practice-oriented. Then, we discuss the factors that influence the TDC development, focusing on the distinction between personal and context-related factors. Finally, we consider the context of VET to present specific teachers profiles and how TDC is integrated into their education. The interplay of these three components paves the way to introduce the study aims and research question.

2.1. Teachers' digital competence (TDC)

'Competence' refers to the mobilisation, combination and active management of situated, anchored-to-the-context resources (i.e. knowledge, know-how, values and attitudes) to cope with complex and constantly evolving professional situations (e.g., Le Boterf, 2000; Zarifian, 2001), which implies the systemic interaction of goals, actors, norms and actions (Nardi, 1996).

2.1.1. The concept of digital competence

'Digital competence' refers to a complex concept, emerging in the literature in the late 1990s as 'digital literacy' (Glister, 1997). After appearing in official documents in 2006 as a key competence for lifelong learning (e.g. Recommendation 2006/962/EC), the term 'digital competence' progressively replaced 'digital literacy' and developed as a historically connotated and stratified, product-independent, transversal and multidimensional concept (Ala-Mutka, 2011; Pérez-Escoda et al., 2019). Calvani et al. (2010) underlined the interplay between three dimensions in digital competence: the technological, ethical and cognitive dimensions. Similarly, Ilomäki et al. (2016) proposed that digital competence comprises four components: "1. Technical skills and practices in using digital technologies […], 2. Abilities to use and apply digital technologies in a meaningful way […], 3. Abilities to understand the phenomena of digital technologies [and] 4. Motivation to participate and engage in the digital culture" (p. 671). Educational policies integrate the increasing awareness of digital competence for citizens and lifelong learners. One of the most popular is DigComp, available in its updated 2.1 version (Carretero et al., 2017). Other models and specific policies have also been developed (see Conrads et al., 2017; Ferrari, 2012), including the KMK Strategy in Germany (KMK, 2016) and the framework for basic digital competence in Switzerland (Swiss Confederation, 2019), referring to it as a basic required competence for citizens to fully participate in civic, social and professional life.

Many education-focused policies in force (see Pettersson, 2018) concern TDC in particular. The issue here is how to organise teacher education and empower teachers so that they can effectively integrate technology into their teaching practice (e.g., Garzon Artacho et al., 2020; Instefjord & Munthe, 2016). In this respect, TDC constitutes an additional layer that teachers must incorporate as education professionals.

2.1.2. *Conceptural and theory-driven frameworks for TDC*

Representative examples of conceptual and theory-driven TDC frameworks are the Technological Pedagogical Content Knowledge (TPACK) model (Koehler et al., 2014; Mishra & Koehler, 2006; Rosenberg & Koehler, 2015) and the Will Skill Tool Pedagogy model (Knezek & Christensen, 2016; Knezek et al., 2000).

The TPACK model is inspired by Shulman's (1986) characterisation of the knowledge that a teacher needs to teach a specific content. It assumes that a digitally competent teacher masters the seven model components: three that correspond to the main knowledge areas (related to disciplinary content, pedagogy and teaching methods and processes, and the use of technologies) and four additional competencies combining each component with the others (pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge and technological pedagogical content knowledge). The model also explicitly considers the role of the context in which teachers act and apply these seven components.

The Will Skill Tool Pedagogy model states that four main factors contribute to the effective technology integration in education. These are the attitudes and beliefs towards instructional use of technology (Will), the ability to use technology and one's confidence, self-efficacy and readiness (Skill), the availability and accessibility of hardware, software and infrastructures (Tool), and, finally, the teaching style and pedagogical practice enacted (Pedagogy).

2.1.3. *Practice-oriented frameworks for TDC*

Practice-oriented frameworks are connected to educational policies such as the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2018) framework; at the European level, there are the framework from the Mentoring Technology-Enhanced Pedagogy (MENTEP, 2018) project, the European Framework for Digital Competence of Educators (DigCompEdu; Redecker & Punie, 2017) and of Digitally Competent Educational Organisations (Kampylis et al., 2015). The last three also propose related instruments to self-assess digital competence, namely, the technology-enhanced teaching self-assessment (TET-SAT) tool (see MENTEP, 2017), the DigCompEdu Check-in Self-Reflection tool (Joint Research Centre, 2020; see Caena & Redecker, 2019; Ghomi & Redecker, 2019; Lucas et al., 2021; see also the DigCompEdu-related tool in Alarcón et al., 2020), and the Self-Reflection on Effective Learning by Fostering the Use of Innovative Educational Technologies (SELFIE) tool (European Commission, 2018). These tools differ in multiple aspects such as the availability of languages and the number of competences they measure.

Taken together, the two sets of frameworks give a complex overview of what TDC entails. We see how the concept goes far beyond the simple mastery of technological tools to include "social, cultural, pedagogical, ethical, and attitudinal dimensions" (Lucas et al., 2021, p. 2) and different sub-areas, *inter alia*, communication and collaboration, the critical use of technology and the selection and creation of digital learning content. TDC goes beyond assuming mastery, requiring appropriation (Aagaard & Lund, 2020). It comprises areas concerning teaching and learning *with* and *about* media (e.g. Tondeur et al., 2018). This distinction is explicit in DigCompEdu, which includes both competences related to the practice of teaching with technologies as well as competences related to fostering the pupils' appropriate digital competence.

TDC should consider the specificities of the educational context. This is especially true in the case of dual VET – i.e., vocational education based on the alternance between a school-based track and a work-based track –, where learning across sites constitutes a challenge for learners (Sappa & Aprea, 2018; Taylor & Freeman, 2011), with different teaching profiles (see section 2.3) and proposals of specific models of technology integration (Schwendimann et al., 2015).

According to Lucas et al. (2021), the available instruments should be adapted to the VET context to effectively grasp the specificities of digital competence in that domain since the available tools present limitations. The six DigCompEdu areas are extensive in terms of content, with numerous related competences that should be considered in detail separately. The corresponding 22-item survey (Caena & Redecker, 2019; Ghomi & Redecker, 2019) assesses each competence with a single item, despite the complexity behind each of these competences. Although the tool shows high reliability and validity (e.g., Lucas et al., 2021), we decided to adapt it slightly to fit the VET context and to make the 22 components more explicit, chunking them into multiple items (see section 3.2 for details).

2.2. *Teachers' personal characteristics and the role of the school context*

Teachers are considered the 'true gatekeepers' (Ertmer et al., 2012) of the digital transformation in schools. Since digital competence is relevant and influential for technology integration in education (Hatlevik, 2017), several studies have focussed on identifying which factors enhance its development. Among these, the teachers' background and personal characteristics (e.g., age, gender, attitudes, beliefs) and school-related factors (e.g., school development, technical infrastructure availability) have been studied in relation to digital competence in previous works.

In terms of gender, some studies have revealed that men are more digitally competent than women (Almerich et al., 2016; Guillén-Gámez et al., 2020, pp. 1–18; Siddiq & Scherer, 2019). However, on the one hand these findings have been contradicted by other research (Krumsvik et al., 2016; Sánchez Prieto et al., 2020; Tondeur et al., 2018); on the other hand these results depend on the type of digital competence considered (Lucas et al., 2021).

Similarly, age is a variable that explains the differences in digital competence among teachers in some studies (Hinojo-Lucena et al., 2019; Krumsvik et al., 2016; Lucas et al., 2021) but not in others (Guillén-Gámez et al., 2020, pp. 1–18; Tondeur et al., 2018). This effect possibly depends on the age variance of the analytical sample. Importantly, the attitude towards technology is a factor that positively influences competence development and technology integration (Ertmer et al., 2012; Tondeur et al., 2018).

Finally, digital tool use has often been associated with higher competence (Hatlevik, 2017; Lucas et al., 2021; Tondeur et al., 2018). Based on the assumption that competence improves with practice, teachers using digital tools in teaching often were more digitally competent (Ghomi & Redecker, 2019).

In the VET context, teachers often continue working as professionals in their domain in parallel to their school activity (see Vocational et al., 2002, Clauses 45–46; Vocational et al., 2002, Clause 47; see also Boldrini et al., 2019), meaning that the teacher workload could represent a personal variable influencing digital competence. However, this factor has not been considered in previous studies when general education teachers were involved.

So far, the research on TDC is mostly focused on individual factors and tends to neglect the school-related factors. Although technological infrastructures and support for TDC development are crucial for the competent pedagogical use of digital technologies in teaching and learning, studies on the effects of organisational infrastructure, leadership support and school digital development on TDC are still scarce (Pettersson, 2018). A few studies have revealed that the availability and the quality of the school digital infrastructure (e.g. classroom equipment, internet access, computer availability) are not related to the use of technology (Gil-Flores et al., 2017) or the TDC (Lucas et al., 2021). However, Lucas et al. (2021) found a significant effect of the students' access to technology on all the digital competences evaluated and a positive effect of the curriculum support on the specific digital competence related to the learners' empowerment and their facilitation of the digital competence. Nevertheless, evidence of the positive effect of school technology development on TDC is still lacking.

The contradictory results from previous studies on TDC, as well as the fact that several of these studies have been conducted with pre-service and not with VET teachers, highlights the need for further research.

2.3. Swiss vocational education and training teachers' profiles

Vocational teachers' profiles vary greatly depending on the context (Misra, 2011). However, the five following general and basic profiles are identified across countries: people working in formal school or college settings; people acting as instructors working in school settings, particularly in vocational laboratories; people working in companies with responsibility for training apprentices as a part of their job functions; people working in labour market training institutions supported by public authorities; and people working in organisations managed by employers' organisations or corporate associations (Grollmann, 2008). Depending on the case, they are identified as teachers, trainers or instructors (Andersson & Köpsén, 2015). Generally, they are designated as 'teachers' when they are active in upper secondary level schools and VET colleges. There is a further distinction between general subject teachers, who usually hold a degree at the tertiary level, and vocational subject teachers who have vocational qualifications and work experience (Misra, 2011). This also applies to the Swiss context, where two main types of VET school teachers exist: those teaching general knowledge (called Language, Communication and Society [LCS] in some contexts) and those teaching profession-specific knowledge (Berger & D'Ascoli, 2012).

Article 46 of the Vocational Training Act and the corresponding Article 46 of the Ordinance that enables its enactment provide three main teaching profiles, depending on whether one is teaching 'vocational subjects', teaching 'general culture' (LCS) or is active in school education within a vocational baccalaureate course (VPETO, 2002). This last categorisation, which is the most official and contextualised, is the one we adopt in our dataset.

When it comes to TDC within VET, our literature review did not reveal any specific characteristic clearly distinguishing the VET population from teachers in general. This aspect seems to be confirmed by different sources: In some publications on VET TDC, there is no mention of the particularities of the VET teachers in terms of competence profile (e.g., Sanchez Prieto et al., 2020; Guggemos & Seufert, 2021). Seufert and Scheffler (2018) focused on the specificities of the VET system and proposed a framework to exploit the interaction between informal and non-formal in addition to formal learning occasions. This constitutes a solution that can also be valid for non-VET teaching staff. More recently, Roll and Ifenthaler (2021) proposed a competence model of multidisciplinary digital competence of vocational teachers. The model includes attitudes towards digitization, handling of digital devices, information literacy, application of digital security standards, virtual collaboration, digital problem solving as well as a demonstration of reflective judgment of one's actions in an interconnected and digital environment. These dimensions are aligned with those of the DigCompEdu, although the authors use a self-developed instrument for their study.

Indeed, these publications refer to the conceptual frameworks mentioned above (see §2.1), such as TPACK or DigCompEdu, even when the focus is on VET teachers. As a consequence, the instruments for measuring TDC in VET are often linked to those frameworks or derive from them.

Finally, a third important source is the official Swiss teaching framework programmes (Swiss Confederation, 2015) which define seven main training objectives for VET professionals, and the related training and qualification plans for teaching (EHB Ausbildung, 2018) which define the competence profile per professionals' category. An analysis of the former source reveals that the essential elements of VET pedagogy for the various categories of VET teaching professionals do not present specificities related to TDC. The specificities are set on a more general basis when the training objectives explicitly refer to the needs of the vocational context and the relationship between the VET learning locations. The latter explicitly mentions technology integration as one of the competences in the VET professionals' profile. The full description first emphasises the pedagogical part and the need to assure technology integration. Then it widens the perspective, referring to the responsibility of developing a critical and conscious approach to technologies and their implications on both the professional and the personal/social life of the learners. Both these sources are fully consistent with the Erfahrraum pedagogical model (Schwendimann et al., 2015), which effectively integrates technologies in the VET context. The main assumption behind this model is that in the VET context, technologies should be mainly exploited to foster the connectivity and the effective alternation of the learners' experiences across the learning locations. Being so specific to dual VET contexts, this aspect is missing in the general instruments we have referred to so far.

2.4. Aims

The present study aims:

1. To measure the digital competence of Swiss VET teachers; an important step to this aim is to validate the self-assessment instrument that measures TDC in VET;
2. To investigate whether digital competence changes depending on the teaching profile; and
3. To investigate whether personal and context-related factors predict VET TDC, confirming the results of similar research conducted outside the VET system. For personal factors, we consider gender, age, workload, attitude towards technology and digital tool use. For context-related factors, we consider the teachers' perception of students' technology access, school digital infrastructure, school curriculum support, support for professional development and school change progress development.

The related research questions are as follows:

RQ1: What is the status quo of Swiss VET teachers' digital competence?
RQ2: What is the relation between VET teachers' profiles and their digital competence?
RQ3: Do personal and school-related factors have a comparable impact on VET TDC as they have on teachers in general education?

There is no hypothesis related to RQ1, as it is a merely descriptive question.

For RQ2, we hypothesised that differences in digital competence occur between different teaching profiles. Based on the specificities of the teachers' activity, for example, we expect that teachers active in general education score higher than their colleagues in the area related to the students' development of digital competence (i.e., *Media Education, Learners' Digital Competence)*.

Finally, given that TDC in the VET context seemingly does not differ substantially from TDC in other educational contexts (see §2.3), we expect that the effect of personal and school-related factors on VET TDC development to be similar to that already documented in other contexts. However, we hypothesise that the workload can constitute an additional factor worth consideration: we expect part-time teachers to have lower TDC than their full-time colleagues.

Table 1
Demographic characteristics of the analytical sample.

Gender	*Male*	*Female*	*Other or Prefer not to say*
N	812	748	132
%	48.8	44.2	7.8

Age range (years)	*< 29*	*30–39*	*40–49*	*50–59*	*≥ 60*	*Prefer not to say*
N	47	324	496	571	148	106
%	2.8	19.1	29.3	33.7	8.7	6.3

Teaching profile	*Professional subjects*	*Vocational baccalaureate*	*General education*
N	967	388	337
%	57.2	22.9	19.9

Language	*German*	*French*	*Italian*
N	944	428	320
%	55.8	25.3	18.9

Note. N = Total number of cases, % = number of cases expressed in percentage.

3. Methods

In this section, we describe the sample of the study as well as the data collection procedure, the self-assessment instrument used and the statistical analyses we conducted to answer our research questions.

3.1. Sample and procedure

Data were collected between June and September 2020 through a self-administered online survey completed by teachers at Swiss VET schools using the Qualtrics software (https://www.qualtrics.com). Teachers from all the VET schools in the country were invited to participate voluntarily via VET institutions (Cantonal offices and school directions). The participants' anonymity was preserved during data collection. The responses of 3404 teachers were collected, and then 779 cases were excluded from the analyses when the questionnaire's completion was less than 100% or when duplicate answer and anomalous response patterns were identified. Professional subject teachers (57.2%), teachers of vocational baccalaureate (22.9%) and general education teachers (19.9%) were selected for the study. The final analytical sample consisted of 1692 teachers from 101 Swiss VET schools, covering all the three main language regions in the country. Of the respondents, 44.2% were women and 48.8% were men (the remaining participants selected the "Other or Prefer not to say" option), while 63% were aged between 40 and 59 years. All demographic characteristics of the study participants are reported in Table 1.

3.2. The self-assessment instrument

The online survey included seven main sections; their composition is briefly described in this section.

3.2.1. Digital Competence Scale for vocational education and training

The Digital Competence Scale for VET comprises 10 subscales that reflect the 22 digital competences of DigCompEdu2.0 (Redecker & Punie, 2017). Forty-five items derived from the 22 DigCompEdu2.0-compliant items (see also Lucas et al., 2021) and other instruments that assess TDC (i.e. SELFIE, Swiss framework for basic ICT skills, TET-SAT, Digital Learning Framework [DLF] evaluation from Educational Research Center, 2018). In addition, seven other items specific to the VET context were created. These items were developed based on the DigCompEdu2.0 competence areas and to a VET-specific model of technology integration (Schwendimann et al., 2015) to assess the degree of teachers' competence in using digital technology to foster connectivity between the three Swiss VET system learning locations (i.e. school, workplace and branch courses). Each item is answered using a 5-point Likert scale to indicate the level of competence, from *Not at all competent* (1) to *Highly competent* (5). The 52 items were distributed over 10 subscales, and the mean scores were calculated using the items from each scale to obtain 10 specific digital competence scores. The subscales are described as follows:

1. *Communication and Collaboration* comprises six items assessing the teachers' technology use for communicating and collaborating with colleagues, professional trainers and external partners (Cronbach's $\alpha = 0.903$);
2. *Professional Development* includes three items referring to the proactivity in developing digital competence and in actively participating in training courses about digital technology use in education ($\alpha = 0.736$);
3. *Digital Resources Selection* consists of three items about the ability of searching digital learning content on the Internet and selecting resources based on the sources' quality and reliability ($\alpha = 0.849$);
4. *Digital Resources Creation* is the ability to create and adapt digital material to specific learning objectives; it is assessed with four items ($\alpha = 0.816$);
5. *Data Protection* comprises six items for evaluating the skills in managing and protecting personal digital resources, data and privacy; it includes the awareness of online risks ($\alpha = 0.892$);
6. *Teaching and Learning* consists of nine items about the ability to integrate technology in teaching to support the learning process and to foster the connectivity between theory and practice ($\alpha = 0.916$);
7. *Assessment* refers to the use of technology to monitor and assess students' learning and provide them with effective feedback; it is evaluated with five items ($\alpha = 0.904$);
8. *Learners' Empowerment* contains six items referring to the ability of offering personalized learning opportunities and of ensuring the inclusion and participation of students in the learning activities ($\alpha = 0.867$);
9. *Media Education* is assessed with four items about the ability to teach students how to recognise the reliability of online information and to sensitise them to responsible technology use ($\alpha = 0.880$); and
10. *Learners Digital Competence* comprises six items about the ability to prepare learning activities that require the students' use of technology with the aim of fostering their digital skills ($\alpha = 0.869$).

An overall mean of the 10 subscales was calculated to have a comprehensive score of TDC that was specific for the VET system.

3.2.2. Attitudes towards technology

Four items derived from inspiring questionnaires used in previous studies (Kothgassner et al., 2012; Initiative D21, 2016) were used to measure the teachers' positive attitudes towards digital teaching and learning methods. The response options ranged from *Absolutely disagree* (1) to *Absolutely agree* (6). Items were averaged to create a compound score with higher values indicating a more positive attitude (α = 0.814).

3.2.3. *Digital tool use*

The frequency of digital tools use for educational purposes was surveyed by asking teachers to report the use frequency of 21 different digital tools (e.g. e-mail, social network, Learning Content Management System platform, software for video conferences, robot, virtual reality) to prepare and conduct teaching activities. The response scale ranged from *Never* (1) to *Very often* (5). The digital use variable was then created to calculate the mean across all 21 items (α = 0.843).

3.2.4. *School context*

Items to measure school context were derived and adapted from the DigCompEdu questionnaire. The teachers were asked to evaluate statements regarding their school on a 5-point Likert scale ranging from *Not at all appropriate* (1) to *Extremely appropriate* (5). The response option "I do not know" was available too. The students' access to technology was assessed with the mean of three items referring to the availability of technology at school, at home and in the workplace for students (α = 0.750); two items about school infrastructure (i.e. availability of an interactive board in the classroom and Internet connection) were averaged to obtain a measure of the school infrastructure ($r = 0.335, p > .001$); and one item assessed the teachers' perception of curriculum facilitation for technology use in the classroom.

3.2.5. *Support for professional development*

The mean score of four items, derived from Eickelmann et al., 2019 and Wendt et al., 2016, was used as a measure of the school's support for professional development in the context of digital transformation. The level of support perceived by teachers was reported on a scale ranging from *Not at all appropriate* (1) to *Extremely appropriate* (6). The response option "I do not know" was available too. (α = 0.840).

3.2.6. *School change progress development*

One item ("How is the state of development of 'digital transformation' in your school?") was used to assess the development of digital change perceived by teachers in their schools. The response scale ranged from *Absolutely not advanced* (1) to *Highly advanced* (6).

3.2.7. *Personal information*

Personal information, such as gender, age, workload percentage and teaching profile (i.e. professional subject teacher, professional baccalaureate teacher, general education teacher) were collected in the last section of the online survey. Considering a cut-off of 0.70 for Cronbach's alpha (Nunnally, 1978), the reliability of all the used scales is adequate.

3.3. *Data analysis*

Overall, the data analysis included (1) a preliminary confirmatory factor analysis to assess the validity of the Digital Competence Scale on our sample of Swiss VET teachers, (2) descriptive statistics to present the status quo of teachers' digital competence (RQ1), (3) analysis of variance of the VET teachers' profiles to investigate possible differences in digital competence across profiles (RQ2), and, finally, (4) simple and multiple regression analyses to evaluate the effect of personal and school-related factors on the teachers' digital competence (RQ3). In the following sub-sections, we provide additional details on each analytical step.

3.3.1. *Preliminary analysis: the factorial validity of the Digital Competence Scale for VET*

To validate the structure of the Digital Competence Scale for VET, a confirmatory factor analysis (CFA) was used. CFA is a statistical technique to evaluate the construct and factorial validity by testing whether the data fit the hypothesised measurement model. Firstly, we estimated the fit of the 52 items in the 10 competence dimensions. Before conducting CFA, the assumptions for univariate and multivariate normality were tested to select the correct method of estimation. The first CFA model was conducted with the 10 correlated first-order latent variables (i.e., the 10 competence subscales). However, because the Digital Competence Scale is hierarchically structured and the alpha coefficients may misestimate the reliability of the total scale score (Black et al., 2015), we assessed the factorial validity by employing a second-order CFA model. The second-order CFA model assumes a second-order factor (i.e., total digital competence) reflecting the overarching construct of digital competence, with direct causal paths to the first-order factors (i.e., the 10 digital competence subscales), which are directly measured through the 52 items. In this model, the covariance between the first-order latent variables was described by the overall second-order latent construct labelled "total digital competence". According to the modification indices, residual correlations were added to improve the model fit of the first- and second-order CFA models. The modifications were made only where appropriate and with strong theoretical justification. The fit of the models was evaluated with several goodness-of-fit indices; because the chi-square assesses the absolute fit of the model, but it can be influenced by sample size, correlations, and variance unrelated to the model. Thus, we also considered the comparative fit index (CFI; acceptable fit $\geq$.90; close fit

Table 2
Results from the Confirmatory Factor Analysis (CFA) of the digital competence measurement.

Digital Competence item		Factor loading		
Factor 1: Communication and Collaboration		λ	SE	p
1.1	*I use digital technologies to communicate with learners and colleagues (e.g. e-mail, school website, platforms such as Moodle, …).*	.842	.010	<.001
1.2	I choose between different communication formats and channels according to audience, context, learning objectives.	.829	.010	<.001
1.3	I use digital technologies to collaborate with colleagues within the school.	.813	.011	<.001
1.4	*I use digital technologies to collaborate with colleagues, also from other schools (e.g. to share experiences, exchange teaching resources, explore new methods, …).*	.714	.016	<.001
11.1	I use digital technologies to communicate with other VET actors (e.g. trainers/trainers in companies, instructors/instructors of inter-company courses, …).	.743	.017	<.001
11.2	I use digital technologies to collaborate with other VET actors (e.g. trainers/trainers in companies and instructors/instructors of inter-company courses).	.673	.018	<.001
Factor 2: Professional Development				
2.1	*I am proactive in developing my skills in the use of digital technologies for teaching.*	.844	.013	<.001
2.2	*I participate in training opportunities through technology* (e.g. MOOCs, webinars, online courses, …).	.685	.019	<.001
2.3	I participate in training opportunities on educational technology, but in a traditional way (face-to-face courses).	.501	.026	<.001
Factor 3: Digital Resources' Selection				
3.1	*I use the Web (search engines, digital archives, websites, specialised blogs, …) to find and select different digital resources.*	.813	.011	<.001
3.2	I apply differentiated search strategies to find digital resources relevant to my objectives.	.877	.010	<.001
3.3	I assess the quality of digital resources based on relevant criteria (e.g. quality, reliability, authoritativeness of the source, …).	.758	.015	<.001
Factor 4: Digital Resources' Creation				
4.1	*I adapt and modify selected digital resources based on relevant criteria (e.g. on the basis of learning objectives, specific needs of PIF and my teaching style).*	.767	.014	<.001
4.2	I create digital resources to support my teaching practice (e.g. multimedia presentations, mind maps, quizzes, videos).	.765	.013	<.001
4.3	I collaborate with my colleagues to create digital resources.	.684	.017	<.001
4.4	Involve learners in the creation of digital learning resources.	.677	.018	<.001
Factor 5: Data Protection				
5.1	I know the privacy and data protection rules and I put them into practice in my work.	.767	.013	<.001
5.2	*I protect sensitive school and learners' data (e.g. test results, written assignments, …).*	.746	.013	<.001
5.3	I respect the copyright of the digital educational resources I use (e.g. I know the different creative commons licenses, I cite sources correctly, I use copyrighted images appropriately, …).	.732	.015	<.001
5.4	I protect my privacy and the privacy of others while online.	.810	.011	<.001
5.5	I am aware of the risks and threats to my personal security in the digital world (e.g. identity theft, fraud, etc.).	.760	.014	<.001
5.6	I restrict access to digital resources appropriately depending on the situation.	.755	.015	<.001
Factor 6: Teaching and Learning				
6.1	*I think carefully about how, when and why to use digital technologies in the classroom, making sure that they are used for the benefit of the learning process.*	.635	.017	<.001
6.2	I use interactive digital tools and resources (e.g. answerers such as Kahoot or Mentimeter, interactive exercises such as LearningApp, h5p, Quizlet, quizzes, and similar), in my teaching.	.710	.014	<.001
6.3	I use collaborative digital tools and resources (e.g. shared whiteboards such as Padlet, collaborative writing tools such as wikis, …) in my teaching.	.722	.014	<.001
6.4	I use digital resources to develop innovative teaching strategies that support learning.	.826	.010	<.001
6.5	*I monitor and moderate the activities and interactions of learners in the digital collaborative environments we use at school*	.768	.013	<.001
6.6	*I teach learners to use digital technologies in collaborative processes and group work for the joint construction and creation of resources, knowledge and content.*	.824	.010	<.001
6.7	*I integrate digital tools into my teaching that help learners to plan, monitor and reflect on their own learning* (e.g. with self-assessment questions, online diaries, e-portfolios, documentation of learning performance).	.756	.012	<.001
11.3	I use digital technologies to foster the connection between learning places (e.g. between school and training company).	.652	.017	<.001
11.4	I use digital technologies to foster the connection between theory and practice, the abstract and the concrete, the general and the particular.	.773	.012	<.001
Factor 7: Assessment				
7.1	*I use digital assessment tools to monitor learners' progress.*	.845	.010	<.001
7.2	I use digital tools to support formative assessment processes.	.874	.009	<.001
7.3	I use digital tools to support summative evaluation processes.	.846	.010	<.001
7.4	*I analyze all the data I have available (e.g. participation levels, performance, online social interactions, grades) to identify which learners may need further support.*	.710	.016	<.001
7.5	*I use digital technologies to provide effective feedback to learners* (e.g. correct answers in quizzes, timely comments, …).	.776	.012	<.001
Factor 8: Learners' Empowerment				
8.1	*I consider any practical or technical difficulties when making deliveries for* learners (e.g. lack of digital skills, unequal access to devices and resources).	.607	.021	<.001
8.2	I recalibrate the task and use other technologies if I notice practical or technical difficulties (e.g. lack of digital skills, unequal access to devices and resources).	.613	.021	<.001
8.3	*I use digital technologies to offer learners personalized and differentiated learning opportunities.*	.756	.014	<.001
8.4	I design and implement tailor-made teaching interventions using digital technologies, differentiating the content of lessons and allowing learners to work at their own pace.	.748	.014	<.001
8.5	*I use digital technologies in my teaching practice to stimulate learners and actively engage them.*	.786	.013	<.001

(*continued on next page*)

Table 2 (*continued*)

Digital Competence item		Factor loading		
8.6	I enable learners to use digital resources and devices to actively participate in classroom activities (e.g. online research, use of spreadsheets, simulations, preparation of presentations, …)	.680	.016	<.001
Factor 9: Learners' Media Education				
9.1	*I teach learners criteria and strategies for assessing the reliability of information gathered online and for identifying fabricated, misleading, or distorted information.*	.729	.016	<.001
9.2	*I teach learners to use digital technologies safely and responsibly.*	.867	.009	<.001
9.3	I make learners aware of the consequences of online misbehavior (e.g. cyberbullying) and teach them what to do if others misbehave.	.787	.013	<.001
9.4	I teach learners to create, adapt and manage their digital identity according to context and purpose.	.837	.012	<.001
Factor 10: Learners' Digital Competence				
10.1	*I prepare deliverables that require learners to use digital tools to communicate and collaborate with each other.*	.770	.012	<.001
10.2	*I prepare deliverables that involve the creation of digital content by learners* (e.g. videos, audio recordings, digital presentations, blogs, wikis).	.752	.014	<.001
10.3	*I encourage learners to use digital technologies creatively to solve concrete problems.*	.786	.011	<.001
11.5	I use technology to support learners in developing their learning and performance documentation (DAP).	.765	.013	<.001
11.6	I prepare deliverables that require learners to use digital tools to communicate and collaborate with external audiences, particularly with their trainer(s) in the company.	.647	.017	<.001
11.7	I ask learners to use digital technologies to inform me about their professional practice (e.g., I ask them to upload digital photos and videos to Moodle or send them via other online sharing tools).	.654	.016	<.001

Note. Factor loadings resulting from CFA (λ) and standard error (SE), N = 1692. Residual correlations between following couple of items were added to the model: item 8.2 with item 8.1 (= 0.515, SE = 0.027, $p < .001$); item 11.2 with item 1.4 (= 0.428, SE = 0.03, $p < .001$); item 6.3 with item 6.2 (= 0.326, SE = 0.03, $p < .001$); item 8.4 with item 8.3 (= 0.35, SE = 0.031, $p < .001$); item 11.2 with item 11.1 (= 0.317, SE = 0.032, $p < .001$). In italics Items retrieved from Lucas et al. (2021).

Table 3
Descriptive statistics of study variables.

Variables	*N*	*M*	SD
Personal factors			
Workload (in %)	1631	73.68	27.05
Attitude [a]	1689	4.43	1.00
Digital Tool Use [b]	1692	2.55	0.61
Contextual factors			
Students Access [c]	1682	3.44	1.00
Infrastructure [c]	1686	3.53	1.09
Curriculum support [c]	1554	3.43	1.16
Support Professional Development [d]	1640	3.55	1.18
School Change Progress Development [e]	1687	4.21	1.10
Digital Competence [f]			
1. Communication and Collaboration	1692	3.43	0.78
2. Professional Development	1692	3.21	0.86
3. Digital Resources' Selection	1692	3.67	0.80
4. Digital Resources' Creation	1692	3.00	0.83
5. Data Protection	1692	3.44	0.80
6. Teaching and Learning	1692	2.79	0.83
7. Assessment	1692	2.68	0.90
8. Learners' Empowerment	1692	3.20	0.74
9. Learners' Media Education	1692	2.77	0.89
10. Learners' Digital Competence	1692	2.72	0.83
Digital Competence Total score	1692	3.09	0.67

Notes. Number of responses (*N*), mean (*M*) and standard deviation (SD).[a] Response scale: *Absolutely disagree* (1) to *Absolutely agree* (6); [b] Response scale: N*ever* (1) to *Very often* (5); [c] Response scale: *Not at all appropriate* (1) to *Extremely appropriate* (5); [d] Response scale: N*ot at all appropriate* (1) to *Extremely appropriate* (6); [e] Response scale: *Absolutely not advanced* (1) to *Highly advanced* (6); [f] Response scale: *Not at all competent* (1) *to Highly competent* (5).

≥ .95; see Brown, 2015), the standardised root mean square residual (SRMR; good fit ≤ .08; see Hu & Bentler, 1999) and the root mean square error of approximation (RMSEA; acceptable fit ≤.08, good fit ≤ .05; see Browne & Cudeck, 1993). Then, we compared the first- and second-order CFAs to evaluate which model fits our data significantly better. All the analyses were run using MPlus, version 7 (Muthén & Muthén, 2015).

3.3.2. Statistical analyses

Univariate normality, normal distribution of residuals and fulfillment of the statistical requirements for the general linear model were tested. Descriptive statistics and bivariate correlation analyses were performed for all study variables. Statistical analyses were conducted using the predictive analytic software IBM SPSS Statistics (version 27).

Analysis of variance (ANOVA) with post hoc testing using the Bonferroni multiple-comparisons test was conducted to compare the three teaching profiles (i.e., professional subject teachers, teachers of vocational baccalaureate and general education teachers) concerning the total digital competence score and the digital competence subscales.

Simple linear regressions were performed to evaluate the effect on the total digital competence of each personal and context-related factor. To evaluate the relation and predictiveness of the personal and context-related factors, considering the variance of both factors, multiple linear regression was applied with the same independent variable. Then, to evaluate the effects of these factors on each specific competence, multiple regression analyses were performed separately on the 10 competence subscales.

4. Results

After providing some information on the factorial validity of the instrument, we comment on the three research questions, by first presenting the descriptive statistics on the status quo of Swiss VET teachers' digital competence, then analysing differences in TDC across teachers' profiles, and, finally, furnishing evidence on the impact of personal and school-related factors on TDC.

4.1. Results of the preliminary analysis: Digital Competence Scale factorial validity

We selected the robust maximum likelihood estimation technique because the assumptions of data normality distribution were violated. The fit indices of the first CFA model were not satisfactory, thus, we added five residual correlations to improve the model fit by reference to the modification indices when in accordance with the hypothesised model of competence. Only inter-item correlations within the same area of competence were added. As a result, the first-order CFA on the 52 items of the Digital Competence Scale showed a good fit: χ^2 (1224) = 5561.240, RMSEA = 0.046, 90% confidence interval (CI) [0.045, 0.047], CFI = 0.912, SRMR = 0.044. Although the chi-square test was significant ($p < .001$), we did not reject the model because the test significance is influenced by the sample size while the other fit indices were satisfactory. The results confirmed the 10-factor structure. Standardised factor loadings ranged from 0.444 to 0.878. All factor loadings are presented in Table 2. The fit of the second-order CFA was also good: χ^2 (1255) = 5955.816, RMSEA = 0.047, 90% CI [0.046, 0.048], CFI = 0.905, SRMR = 0.047. All 10 factor loadings were high (from 0.675 to 0.978). To compare the first- and the second-order CFA the scaled chi-square difference test, $\chi s^2 = (\chi r^2 * c_r - \chi l^2 * c)/cd$, was computed because the two models are nested (second-order CFA is nested in the first-order CFA). The comparison between the two models suggested that the first-order CFA model fits the data significantly better ($p < .001$) compared with the narrower one.

Table 4
Correlations between study variables.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Gender [a]	1									
2. Age	-.065*	1								
3. Workload	-.193***	.122***	1							
4. Attitude	-.177***	-.126***	.085***	1						
5. Digital Tool Use	-.010	-.107***	.121***	.398***	1					
6. Students Access	-.101***	-.022	-.035	.278***	.255***	1				
7. Infrastructure	-.071**	.021	-.067**	.187***	.173***	.606***	1			
8. Curriculum support	-.045	-.006	-.010	.238***	.266***	.504***	.370***	1		
9. Support Professional Development	-.008	-.005	-.053*	.105***	.093***	.308***	.252***	.357***	1	
10. School Change Progress Development	-.007	-.081**	-.046	.112***	.151***	.473***	.431***	.411***	.463***	1
11. Digital Competence Total Score	-.121***	-.115***	.181***	.558***	.645***	.315***	.220***	.354***	.194***	.221***

Note. *$p < .05$, **$p < .01$, ***$p < .001$; [a] 0 = male, 1 = female.

4.2. Descriptive statistics

The general descriptive statistics of all variables are presented in Table 3. For the scores related to TDC, overall, the highest mean score was observed for *Digital Resources Selection* and the lowest for the *Assessment* competence. The attitude towards technology was highly positive as was the school change progress development perceived by teachers. The mean of the total digital competence score was above the average score. Correlations between personal characteristics, school-related factors and digital competence (total score) are shown in Table 4. The total score of digital competence significantly and positively correlates with all the study variables except gender and age, which exhibits a negative correlation.

4.3. Digital competence differences between teaching profiles

The ANOVA results partially confirm our hypothesis. No significant difference in the total digital competence scores between the three different profiles was found, F (2, 1689) = 0.888, p = .412. However, considering the 10 competences separately, significant differences emerged in the four following cases: *Professional Development*, F (2, 1689) = 3.879, p = .021, η^2 = 0.005, 95%CI [0.000, 0.012]; *Digital Resources Selection*, F (2, 1689) = 9.590, p < .001, η^2 = 0.011, 95%CI [0.003, 0.023]; *Media Education*, F (2, 1689) = 17.444, p < .001, η^2 = 0.020, 95%CI [0.009, 0.035]; and *Learners Digital Competence*, F (2, 1689) = 4.221, p = .015, η^2 = 0.005, 95%CI [0.000, 0.013]. The effect sizes were small in all four cases (Kirk, 1996). Bonferroni multiple-comparison tests revealed that professional baccalaureate teachers are significantly more competent compared with professional subject teachers for the two competences related to *Professional Development*, mean difference [MD] = −0.129, 95%CI [−0.254, −0.006], p = .037, and *Digital Resources Selection*, MD = −0.178, 95%CI [−0.292, −0.063], p < .001. LCS teachers are significantly more competent than the other two profiles in the sub-area related to *Media Education*, MD with professional subject = .320, 95%CI [0.187, 0.453], p < .001 and MD with professional baccalaureate = .308, 95%CI [0.151, 0.465], p < .001, more competent than professional baccalaureate in concerning *Learners Digital Competence*, MD = −0.158, 95%CI [−0.307, −0.010], p = .032, and more competent than professional subject teachers in the *Digital Resources Selection* competence, MD = −0.165, 95%CI [−0.286, −0.044], p = .003. Finally, professional subject teachers reported higher *Learners Digital Competence* than professional baccalaureate teachers did, MD = −0.130, 95%CI [−0.250, −0.010], p = .028. Table 5 shows the mean and standard deviation for each profile in each competence.

4.4. The effects of personal and contextual factors on digital competence

To examine the relation between each personal and context-related factor and the digital competence score, simple linear regressions were first executed. The regression coefficients, standard errors, t-values, and confidence intervals are presented in Table 6. All variables tested were statistically significant predictors of the total digital competence score in simple linear regression. The higher significant positive effects are due to personal factors, such as positive attitudes towards technology use and digital tool use frequency. Gender and age showed negative effects on competence, revealing that being female negatively affects the competence score, whereas older teachers report lower digital competence. However, the explanatory level of R^2 was relatively low for all simple linear regression models.

Table 5
Mean and standard deviations of digital competence for the three teaching profiles.

	Professional subjects (N = 967)		Professional baccalaureate (N = 388)		General education (N = 337)	
	M	SD	M	SD	M	SD
Digital Competence Total Score	3.08	.693	3.09	.634	3.13	0.63
Communication and Collaboration	3.48	0.80	3.62	0.73	3.51	0.77
Professional Development	3.16	0.86	3.29	0.89	3.26	0.84
Digital resources' Selection	3.60	0.82	3.78	0.77	3.76	0.77
Digital Resources' Creation	2.93	0.86	2.84	0.82	2.94	0.83
Data Protection	3.39	0.79	3.42	0.75	3.34	0.76
Teaching and Learning	2.86	0.85	2.81	0.83	2.92	0.80
Assessment	2.68	0.93	2.70	0.87	2.66	0.87
Learners' Empowerment	3.19	0.75	3.19	0.74	3.24	0.70
Learners' Media Education	2.66	0.89	2.72	0.89	3.01	0.77
Learners' Digital Competence	2.90	0.91	2.79	0.91	3.01	0.86

Note. M = Mean, SD = Standard deviation, N = total number of cases.

Table 6
Simple linear regression on Digital Competence Total Score.

Variable	B	SE	T	95% CI	
				LL	UL
Gender [a]	-.161***	.033	−4.814	-.226	-.095
Age	-.077***	.017	−4.614	-.110	-.044
Workload	.004***	.001	7.439	.003	.006
Attitude	.372***	.013	27.618	.346	.399
Digital Tool Use	.712***	.021	34.721	.672	.753
Students Access	.210***	.015	13.583	.179	.240
Infrastructure	.135***	.015	9.259	.107	.164
Curriculum support	.204***	.014	14.903	.177	.231
Support Professional Development	.109***	.014	8.007	.083	.136
School Change Progress Development	.134***	.014	9.321	.106	.162

Notes: *$p < .05$; **$p < .01$; ***$p < .001$; B = unstandardized regression coefficient; SE = standard error; t = *t*-statistic value; CI = confidence interval; LL = lower limit; UL = upper limit. [a] 0 = male, 1 = female.

A multiple linear regression with all the previous independent variables and total competence score was executed to evaluate the relation and predictiveness of personal and contextual factors, considering the variance of both factors. Because of listwise missing deletion, the sample size for this analysis consisted of 1333 teachers. The final model explained 55.2% of the variance in the overall digital competence score. When comparing the simple and multiple regression results, the size and significance of coefficients varied. Gender was no longer significant, and contextual variables related to infrastructure and students' access lost their significant effect. Curriculum and professional development support and school change progress development variables lost power of explanation but remained significant. What did not change was the role of attitudes and tool use, which remained the factors most affecting digital competence. Details are presented in Table 7.

Ten other multiple linear regressions were conducted for the specific digital competences in turn to analyze the effects of personal end contextual factors on the different, single components of digital competence (see Table 8 for details).

Workload, attitudes towards technology use, digital tool use frequency and curriculum support showed a significant impact on all 10 subscales of specific competences.

Among the considered personal factors, the effect of gender was not significant in *Communication and Collaboration* or *Digital Resources Creation* competence, but it significantly favoured women in the *Professional Development* and *Learners Empowerment* competences. Instead, men showed significantly more ability than women in the other competences.

Age had a negative and significant impact on areas 1, 3, 4 and 6 and a positive effect on the *Data Protection* competence. Workload affected all competence dimensions, showing that the more time load a teacher has, the greater that person's competences will become. Based on this first result, we further investigated the effect of workload on digital competence, distinguishing post hoc between those teaching less than 50% of a full workload (who follow a different training plan; see VPETA, 2002) and those teaching full time. Although a clear profile did not emerge for baccalaureate and LCS teachers, in the case of professional subject teachers, the contrast was significant in all ten competences, $p < .001$, with higher scores in favour of full-time teachers (see Table 9 for details).

Regarding contextual variables, the students' access to digital devices and the school infrastructure did not affect any teacher competences; the teachers' perception of curriculum support influenced all 10 sub-competences; and the support for professional development affected digital competence as a whole and particularly the *Professional Development* competence. The perception of school development positively affected the total digital competence score; however, examining the effects on the other competences, there were significant effects only in areas 4, 6, 7 and 8.

Table 7
Multiple linear regression on Digital Competence Total Score.

	R^2	Adj. R^2	*F*	B	SE	T	*p*	95% CI	
	0.552	0.549	F (10, 1322) = 162.948***					LL	UL
Constant				.361***	.098	3.691	<.001	.169	.553
Gender [a]				-.046	.025	−1.816	.070	-.096	.004
Age				-.026*	.013	−2.051	.041	-.051	-.001
Workload				.003***	.000	5.610	<.001	.002	.004
Attitude				.208***	.014	14.819	<.001	.181	.236
Digital Tool Use				.496***	.023	21.282	<.001	.450	.542
Students Access				.007	.017	.409	.683	-.027	.041
Infrastructure				.000	.015	.017	.986	-.028	.029
Curriculum support				.059***	.013	4.579	<.001	.034	.084
Support Professional Development				.028*	.012	2.317	.021	.004	.051
School Change Progress Development				.034*	.014	2.362	.018	.006	.062

Notes: *$p < .05$; **$p < .01$; ***$p < .001$; B = unstandardized regression coefficient; SE = standard error; t = *t*-statistic value; CI = confidence interval; LL = lower limit; UL = upper limit. [a] 0 = male. 1 = female.

Table 8
Regression coefficients on all digital competence sub-scales.

	Total score		1. Communication and Collaboration		2. Professional development		3. Digital Resources' Selection		4. Digital Resources' Creation		5. Data Protection		6. Teaching and learning		7. Assessment		8. Learners' Empowerment		9. Learners' Media Education		10. Learners Digital Competence	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Gender [a]	-.046	.025	-.010	.035	.159***	.040	-.085*	.038	-.051	.034	-.125**	.040	-.067*	.033	-.112**	.040	.101**	.033	-.141***	.042	-.130***	.034
Age	-.026*	.013	-.046**	.017	.017	.020	-.108***	.019	-.075***	.017	.042*	.020	-.037*	.016	-.022	.020	-.011	.017	-.012	.021	-.006	.017
Workload	.003***	.000	.003***	.001	.003***	.001	.003***	.001	.003***	.001	.002*	.001	.003***	.001	.002**	.001	.003***	.001	.004**	.001	.002***	.001
Attitude	.208***	.014	.251***	.019	.246***	.022	.197***	.021	.255***	.019	.171***	.022	.225***	.018	.204***	.022	.179***	.018	.144***	.024	.212***	.019
Digital Tool Use	.496***	.023	.405***	.032	.476***	.037	.349***	.035	.547***	.031	.300***	.037	.647***	.030	.581***	.037	.451***	.031	.559***	.039	.646***	.031
Students Access	.007	.017	.005	.024	.009	.027	.026	.026	.004	.023	.001	.027	-.015	.022	.002	.028	.029	.023	-.010	.029	.020	.023
Infrastructure	.000	.015	-.036	.020	.016	.023	.028	.022	.019	.019	-.009	.023	.027	.019	.012	.023	-.023	.019	-.028	.024	-.002	.019
Curriculum support	.059***	.013	.049**	.018	.049*	.020	.043*	.019	.063***	.017	.047*	.020	.060***	.017	.066**	.020	.067*	.017	.063**	.022	.082***	.017
Support Professional Development	.028*	.012	.038*	.016	.052**	.019	-.001	.018	.018	.016	.037*	.019	.016	.015	.036	.019	.026	.016	.035	.020	.021	.016
School Change Progress Development	.034*	.014	.021	.020	-.008	.023	.011	.021	.044*	.019	.039	.023	.064***	.018	.052*	.023	.041*	.019	.039	.024	.036	.019
R^2 (R2 -Adjusted)	.552 (.549)		.370 (.365)		.329 (.323)		.293 (.288)		.481 (.477)		.207 (.201)		.523 (.520)		.380 (.375)		.370 (.366)		.305 (.300)		.499 (.495)	

Notes: *$p < .05$; **$p < .01$; ***$p < .001$; N = 1333; B = unstandardized regression coefficient; SE = standard error; [a] 0 = male. 1 = female.

Table 9
T-test results comparing full time and part-time (<50%) professional subjects' teachers on digital competence.

	Workload	N	M	SD	t	df	MD	95% CI	d	95% CI
Communication and Collaboration	<50%	225	3.27	0.73	−5.33***	509.35	−0.35	[-0.48, −0.22]	-.455	[-.627, −.282]
	Full-time	323	3.62	0.80						
Professional Development	<50%	225	3.00	0.88	−4.42***	546.00	−0.33	[-0.47, −0.18]	-.384	[-.555, −.212]
	Full-time	323	3.33	0.83						
Digital Resources' Selection	<50%	225	3.55	0.81	−3.25***	546.00	−0.22	[-0.36, −0.09]	-.282	[-.453, −.111]
	Full-time	323	3.77	0.79						
Digital Resources' Creation	<50%	225	2.85	0.84	−5.22***	546.00	−0.39	[-0.53, −0.24]	-.453	[-.625, −.280]
	Full-time	323	3.24	0.86						
Data Protection	<50%	225	3.34	0.81	−4.01***	546.00	−0.28	[-0.42, −0.14]	-.348	[-.519, −.176]
	Full-time	323	3.63	0.82						
Teaching and Learning	<50%	225	2.60	0.81	−6.36***	546.00	−0.47	[-0.61, −0.32]	-.552	[-.725, −.379]
	Full-time	323	3.07	0.88						
Assessment	<50%	225	2.53	0.85	−5.64***	546.00	−0.44	[-0.59, −0.29]	-.489	[-.662, −.317]
	Full-time	323	2.97	0.94						
Learners' Empowerment	<50%	225	3.02	0.72	−5.37***	546.00	−0.35	[-0.47, −0.22]	-.466	[-.638, −.294]
	Full-time	323	3.37	0.76						
Learners' Media Education	<50%	225	2.45	0.90	−7.20***	546.00	−0.55	[-0.71, −0.40]	-.625	[-.799, −.451]
	Full-time	323	3.01	0.88						
Learners' Digital Competence	<50%	225	2.61	0.83	−5.29***	546.00	−0.39	[-0.53, −0.24]	-.460	[-.632, −.287]
	Full-time	323	3.00	0.85						
Digital Competence Total score	<50%	225	2.92	0.66	−6.31***	546.00	−0.38	[-0.49, −0.26]	-.548	[-.721, −.375]
	Full-time	323	3.30	0.70						

Notes. N = Number of responses, M = mean, SE = standard deviation, t = *t*-statistic value; df = degree of freedom, MD = mean difference, CI = confidence interval, d = Cohen's *d*.

5. Discussion

The present study aimed to measure the digital competence of Swiss VET teachers using an instrument previously applied and found to be reliable but focusing on the specific characteristics of the vocational context. In this vein, looking for possible differences in digital competence depending on the teachers' profiles constituted a specification of the first aim of the study.

Overall, considering that the total digital competence score settled at a mean value of 3.09 on a 5-point Likert scale, which is above the average score, we consider this result aligned with those from similar studies conducted in non-VET contexts (Benali et al., 2018; Ghomi & Redecker, 2019; Lucas et al., 2020).

Analysing the specific scores obtained for each of the 10 sub-competences, we found that the *Digital Resources Selection* competence was on average the most developed by all teachers. Meanwhile, the *Assessment* competence was the weakest. A possible explanation of these results is that selecting digital resources is the most common and needed activity in teaching. Moreover, it is based on pedagogical skills than specifical digital competences. Instead, since the assessment methods are usually based on examinations, scores and rankings, teachers may still refrain from using different assessment formats and approaches that require the use of digital technology.

No significant differences in the overall digital competence were found among teacher profiles, which supports the idea of uniform development of this competence in the VET teaching staff. Looking at the single sub-competences, there are indeed some significant differences depending on the profile, although they are minor (small effect sizes). These differences can be explained by the role teachers have in the curriculum. For example, LCS teachers score higher for *Media Education* than the other two profiles, possibly because the issues related to this competence (e.g., responsible technology use and data protection) are closer to the LCS curriculum and organisation than to professional subjects. In the latter case, a direct connection to *Media Education* is less likely to occur spontaneously.

Other differences could be related to the teachers' educational and professional background. Professional baccalaureate teachers usually have an academic profile and are teachers of a specific discipline. This could explain a more 'traditional' approach to teaching and a lower score on the *Learners Digital Competence*, which requires a more student-centred approach. Their specific education could also explain why they are more prepared when selecting digital learning content.

The second aim was related to investigating whether personal and context-related factors predict VET TDC. As for gender, the results of our study highlighted that women and men perform better in different areas. Although the difference in the overall competence is not significant, women are significantly more competent compared with men in using technology to personalise and differentiate learning following the learners' individual needs and to stimulate and engage students in learning activities to empower the learning process. Moreover, women invest more effort in personal professional development about educational technology than men. By contrast, men have higher competence in most of the activities that specifically require the use of technological tools for teaching and learning (i.e., areas 3, 6, 7 and 10) and in the abilities that assume knowledge about data protection, privacy management and online security (i.e., areas 5 and 9).

This differentiated analysis could explain the mixed results of the literature when looking for a higher-order category, such as the overall digital competence score analysis. However, we must consider that men tend to overestimate their digital abilities and they have higher computer self-efficacy than women do (Durndell & Haag, 2002).

In contrast to previous studies with pre-service teachers (Tondeur et al., 2018), the present study is characterised by a wider variance in the age of the sample. Overall, our results are in line with the previous findings that competence decreases with age (Hinojo-Lucena et al., 2019; Krumsvik et al., 2016). Specifically, like Lucas et al. (2021), we found a negative and significant effect of age on the overall digital competence and on the ability to select and create digital resources for teaching. The only exception is the *Data Protection* competence, for which the effect was significant but positive, revealing that more aged teachers are more competent in protecting personal data and privacy online than their younger counterparts. This result could be explained by a higher online privacy risk perception in a higher age (Oomen & Leenes, 2008), which could lead to the development of the related competence.

We also considered the workload percentage, which is something that previous research lacked but could be relevant in the context of VET education. Indeed, our results show that a higher workload percentage is related to higher competence scores in all 10 sub-competences, as well as to the overall digital competence score. The fact that workload determines how digital competence develops could be due to professional subject teachers in VET often having less time to train and develop their pedagogical profile, as most of them continue working as professionals in parallel to teaching. The comparison of full-time and part-time teachers on digital competence scores confirmed that professional subjects teachers working less than 50% of a full workload have significantly lower competences than full-time teachers. Since this is the first time that workload is shown to affect digital competence, it is worth to be further investigated in future studies.

Attitudes towards technology and digital tool use frequency are central determinants of digital competence. Their positive and significant effect was confirmed on all 10 analysed competences, confirming previous results (see Ertmer et al., 2012; Tondeur et al., 2018, for the attitude towards technology; see Ghomi & Redecker, 2019, for the frequency of digital tools use).

Since digital competence is not an isolated phenomenon on the individual teacher level (Pettersson, 2018), in this study, teachers' perceptions about the school context were also considered as factors that potentially influence TDC. It is possible to distinguish between the school's infrastructural characteristics (i.e., students' access and school infrastructure) and subjective perceptions of the school context where teachers work (e.g., supportive school management, school digital development). According to our data, the former does not influence digital competence, and these results are in line with previous findings by Lucas et al. (2021), where classroom equipment and network infrastructure did not affect the digital competence score.

In contrast, the teachers' perception of school support for professional development positively and significantly affects the competence for professional development, suggesting that teachers working in schools where lifelong learning is supported are more prone to actively engage in training activities and take advantage of the training opportunities given.

The perception of the school progress development has a significant impact on the competences that require a higher ability to integrate technology into teaching and learning (e.g., digital resources' creation, assessment, learners' empowerment) but not on basic digital skills (e.g., communication and collaboration, digital resources selection). These results suggest that a school culture supporting the successful integration of technology in education is a requirement for developing the teachers' advanced digital competences and for effectively promoting the digital transformation of VET education.

Finally, among the context-related factors, curriculum support is the only one that has a positive effect on all 10 sub-competences. It also has the greatest effect on the overall competence score even if this is smaller than the effects of positive attitudes and digital tool use. The latter variables are the most relevant factors affecting TDC among the ones considered here. Hence, our findings are in line with previous research on TDC that highlighted the prevalent effect of personal factors in contrast to contextual ones (Lucas et al., 2021).

5.1. Limitations

Despite its strengths, this study presents some limitations. The school-context factors were measured through the teachers' subjective perception, which cannot be considered equivalent to an objective measurement of the school environment. Further research should objectively consider school factors (e.g., the number of technological devices for teachers and students, the schools' digitalisation level, the teachers' training opportunities) because digital competence is not a phenomenon that stands apart from the context. Instead, internal and external factors interact and define competence development. For example, personal attitudes towards technology use and competence development can be supported or hindered by school characteristics or requests, the presence of obstacles or facilitators in the external environment of the teachers, etc. Objective measurements of the school context could be useful for a multi-level design of analyses.

Moreover, the study was conducted on a voluntary and self-reported competence assessment. In terms of the gender-related aspect, self-reported measurements could be under- or overestimated compared with the objective methods for measuring competences. Future research should consider integrating concrete tasks, to guarantee an objective assessment of the real level of attained competence.

5.2. Conclusions

This study had three main aims. The first was to provide a snapshot of the status quo of the teachers' digital competence (TDC) on a sample of 1692 Swiss VET teachers participating in a survey that used an assessment instrument that relies on previously validated questionnaires, also taking into account the specificities of the VET context. This first aim also gave us the possibility to check for the validity of the adapted VET-oriented TDC instrument. Secondly, we aimed at testing for possible differences in TDC depending on the VET teachers' profiles. Finally, the third aim was related to investigate whether personal and context-related factors play a similar role in VET as they do in other educational settings.

The results confirm the validity of the 10-dimensional structure of the TDC assessment instrument used and indicate that VET teachers place themselves at a similar degree of digital competence compared to previous research, with a few and minor differences across profiles. Moreover, multiple regression analysis highlights that among the personal factors, attitude towards technology and digital tool use frequency play a principal role in TDC development, together with teachers' workload, which was rarely considered in previous studies. For the context-related factors, curriculum support has the greatest effect on TDC, although it is smaller than that of personal factors.

Overall, the study significantly contributes to the topic of TDC. First, it provides policymakers with an overview of digital competence among vocational education teachers, which was missing until now. In addition, it provides teacher educators and teachers with a useful tool as it revealed a valid and reliable factorial structure to measure different aspects of TDC. This means that a fine-grained tool differentiates among the 10 competence areas that can be considered separately. Thus, the VET Digital Competence Scale is a useful self-assessment tool to make teachers aware of personal strengths and weaknesses related to their digital competence. Consequently, it can be used in various teacher education programmes to identify the status quo at the beginning of training and the areas worth investing more effort and development. Teacher educators can use it to identify needs for further training and to develop targeted training offers. Finally, from a research point of view, the instrument we used to measure TDC can be further improved: in this direction, validating a short version of the scale might be very useful for further research on digital competence in VET.

Credit author statement

Alberto Cattaneo: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision. Chiara Antonietti: Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. Martina Rauseo: Formal analysis, Investigation, Visualization.

Declaration of competing interest

None.

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