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The role of personal and contextual factors when investigating technology integration in general and vocational education

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ABSTRACT

This study aims to investigate the extent to which perceived personal and school-related factors influence the quality of technology integration in teaching at the upper secondary level and how this differs between general and vocational education. The quality of technology integration was operationalised through the different activities supported by technology according to the ICAP model. We used data from a survey of 1660 teachers from 106 upper secondary schools in Switzerland to construct structural equation models of the interplay between school-related factors, teacher-related factors, and technology integration. Apart from confirming that technology integration is generally high across all school types, the study shows that among school-related factors, goal clarity is a significant predictor of constructive learning activities and of all the three personal factors considered in the study: teachers' positive beliefs, technological knowledge, and technological pedagogical content knowledge. Moreover, these personal factors, in turn, constitute significant predictors of all the four types of learning activities. Both full-time and dual vocational schools integrate constructive and interactive activities more than general schools, and vocational teachers report significantly higher beliefs and lower technological pedagogical content knowledge than general school teachers. These findings confirm the importance of considering the interplay between personal and school-related factors when training teachers in technology integration, with interesting differences across school types that seem to depend more on the contextual culture than on the curriculum organisation.

1. Introduction

Teachers play an outstanding role in integrating technology into education and consequently in preparing students for a digitally moulded future (Backfisch et al., 2020; Lachner et al., 2024). Although teacher education has focused on this for years (e.g. Eberle, 1997) and despite some improvements, training teachers to use digital technology in education remains a challenge (e.g. Nagel et al., 2023). Understanding which factors drive effective technology integration in education is therefore of pivotal importance. Although different models of technology integration exist (e.g. Niederhauser & Lindstrom, 2018), they all generally distinguish between personal or teacher-related factors and contextual or school-related factors. Concerning personal factors, beyond considering personal characteristics such as age, gender, technology use, and years of teaching, scholars usually distinguish between value and ability beliefs (e.g. Backfisch et al., 2021). The latter is often measured via self-reported data in terms of perceived competence and, thus, is not distinguished from (ability) beliefs (Cheng et al., 2020). Acknowledged models of technology integration based on personal factors include the technology acceptance model (TAM; Davis, 1989) and the will-skill-tool-pedagogy model (WSTP; Knezek & Christensen, 2016). For school-related factors, scholars have focused their attention on infrastructure (e.g. Gil-Flores et al., 2017), as well as on elements such as formal and informal training and collaboration opportunities, school culture, and type of leadership (e.g. Dexter, 2018; Dexter & Richardson, 2020; Petko et al., 2018).

Several studies have investigated these factors at different educational levels. However, upper secondary education, which in some countries includes general education (high schools) and vocational education (now called 'career and technical education' in the United

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States; see Durham & Bragg, 2019), remains under-investigated. These two systems differ in their approaches and in the organisation of their curricula. General education curricula are more academic and theory-oriented, organised around subjects and most often based on a full-time school-based track, whereas vocational education curricula are more practice-oriented, shifting away from a subject-led approach and often combining school-based and work-based tracks (Fürstenau et al., 2014; Pilz & Fürstenau, 2019; Strahm et al., 2016). Moreover, teaching in vocational education is very demanding and involves the treatment of many aspects in a short period of time, which often results in very instructive and teacher-centred delivery. The time for teaching and learning in vocational schools is much more restricted than in general education, which is also a constraint for active learning and content-based in-depth acquisition of knowledge (Holtsch et al., 2019; Schütte, 2020). All these differences could imply that technology integration takes place differently in general and vocational education. However, research has rarely investigated whether the factors that lead to technology integration differ between the two systems. This research gap is not surprising, because on a world scale, most secondary schools are not so specific, and a 'vocationalised secondary education' can still be considered a recent phenomenon (see Guile & Unwin, 2019a; Lauglo, 2005).

Finally, technology integration has often been investigated by examining the frequency (quantity) of technology use. However, scholars are increasingly considering the quality of integration (Antonietti et al., 2023; Fütterer et al., 2022; Juuti et al., 2022), which could contribute to shift the research focus from a product-oriented to a process-oriented quest (Kopcha et al., 2020; Lachner et al., 2024), fostering new insights on the topic.

Based on these premises, this study aims to investigate the extent to which perceived personal and school-related factors affect the quality of technology integration in teaching at the upper secondary level and particularly whether this differs depending on the school type—general versus vocational. Understanding these differences is useful from a theoretical point of view to investigate the extent to which differences in the quality of technology integration are related to different personal and school-related factors and whether differences between educational systems are mirrored in practice. From a practical perspective, the study contributes to a better grasp of the process of integrating technology into teaching, identifying its most relevant factors, which could enhance the design of teacher education programmes across educational systems.

In the following sections, we delve deeper into the available literature on the factors contributing to technology integration. We then present the characteristics of the two educational systems in more detail, followed by a report on our empirical study.

1.1. Models of technology integration and the role of personal and school-related factors

In this section, we begin by introducing some acknowledged models of technology integration before emphasising some overlaps and correspondences between them in dealing with personal and school-related factors. We also provide a brief commentary on the interplay between these two types of factors.

Technology integration models vary in their approach—identifying either the barriers to be removed or the proficiencies needed for successful integration; however, they generally identify factors on two levels: the personal level and the school-related level. For example, the Barrier to Technology Integration model (Ertmer, 1999; Ertmer et al., 2012; Ertmer & Ottenbreit-Leftwich, 2010) identifies first-order and second-order barriers to technology integration. First-order barriers include resource barriers (e.g. access to technology, availability of technical support) and institutional barriers (e.g. leadership support, institutional culture and availability of a school strategy for technology integration, and formal and informal professional development opportunities; Bowman et al., 2020; Ertmer & Ottenbreit-Leftwich, 2010). Second-order barriers encompass knowledge and skills concerning the importance of technology integration. Knowledge and skills, together with attitudes, constitute separate and different components of competence (e.g. Baartman & de Bruijn, 2011; LeBoterf, 1994); however, in discussing technology, scholars often use the overarching term "digital competence" without clear distinction (Ilomäki et al., 2014). Moreover, as knowledge and skills are usually collected through self-reported measures, scholars also refer to them as beliefs. We can differentiate value beliefs, such as the perceived usefulness of integrating technologies into teaching, from ability beliefs, such as self-efficacy beliefs, that is, the expectancy of being able to cope with a task (in our case, the use of technology in teaching; Backfisch et al., 2021; Bowman et al., 2020). Important collective efforts have been made to minimise the negative effects of first-order barriers (Bowman et al., 2020; Ertmer, 2005). In technologically developed countries, the role of first-order barriers is actually minor (Schmitz et al., 2022). Nevertheless, the absence of these barriers cannot be taken for granted or their effects neglected (Cheng & Parker, 2023), especially for contexts where the level of technology adoption is still relatively low (Morales Velasquez, 2007).

A possible theoretical underpinning of the barrier model is the expectancy–value theory (EVT; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000; Wigfield et al., 2009), which also considers human behaviour as determined by both personal and school-related factors (Cheng et al., 2020). EVT also partially overlaps (Ranellucci et al., 2020) with another widespread model of technology integration: the Technology Acceptance Model (TAM; Davis, 1989; Venkatesh & Davis, 1996; for an overview about its further evolution, see Taherdoost, 2018). The TAM essentially proposes that the actual use of technology is a function of one's behavioural intention to use it, which, in turn, is determined by the perceived ease of use and perceived usefulness of technology. Some later elaborations of the model also included computer self-efficacy—corresponding to ability beliefs. Recent research has confirmed the predominant role of perceived usefulness as a predictor of behavioural intention and actual use of technology by teachers (Fütterer et al., 2023; Scherer et al., 2019; Scherer & Teo, 2019).

Furthermore, the role of teachers' self-efficacy in technology use has been confirmed as a central factor. For example, Gerick et al. (2017) used a multilevel structural equation model applied to a large-scale dataset from the International Computer and Information Literacy Study (ICILS; Fraillon et al., 2014) and found that ability beliefs (operationalised as self-efficacy in using technologies) was the most prominent factor related to technology use in class in all four countries considered (Australia, Germany, Norway, and the Czech Republic). Backfisch et al. (2021), beyond confirming a strong direct effect of self-efficacy on teachers' technology use in the classroom, also showed that a specific technology integration-related self-efficacy is crucial. Recently, the interplay between teachers' beliefs about the perceived usefulness of technology integration and their beliefs about their digital competence has also been investigated, showing positive and significant relationships between the two and between perceived usefulness and behavioural intention (Antonietti et al., 2022). This is also true with actual use: perceived digital competence (i.e. ability beliefs) directly and indirectly affects technology use, and this relationship is mediated by perceived usefulness (Cattaneo et al., 2024).

Finally, one of "the most comprehensive models to date for examining instructional technology integration" (Niederhauser & Lindstrom, 2018, p. 9) is the Will-Skill-Tool-Pedagogy model (WSTP; Knezek & Christensen, 2016; Knezek et al., 2000). The WSTP model also considers both personal and school-related aspects. According to this model, will, skill, tool, and pedagogy are the four factors influencing and contributing to the integration of technology in teaching. The 'will' component corresponds to the teachers' beliefs towards the use of technology. The 'skill' component includes both the ability to use technology and "the self-perceived confidence (self-efficacy) and readiness to use technology" (Knezek & Christensen, 2016, p. 311). The 'tool' component refers to the availability and accessibility of hardware and software, that is, of

Table 1
Overview of the main overlaps and possible 'jangle fallacies' across the presented models of technology integration.

WSTP	TPACK	Technology Acceptance Model	Barrier to Technology Integration model		Expectancy-Value Theory
School-readiness - Tool			First-order barriers	Resource barriers (access to technology, availability of technical support)	
School-readiness				Institutional barriers (**leadership support, institutional culture, formal and informal collaboration**)	
Teacher-readiness			Second-order barriers	Knowledge, skills, attitudes and beliefs, and in particular:	
- **Will**		Perceived usefulness		- Value beliefs	Value beliefs (intrinsic value, attainment value, **utility value**, and costs)
- **Skill**	**TK**	Ease-of-use, Computer self-efficacy		- Ability beliefs	Ability beliefs (expectancy and **ability/self-efficacy beliefs**)
- **Pedagogy**	**TPCK**				

Note. The dimensions reported per each technology integration model are not always exhaustive of the entire model but constitute a functional selection for the presentation of their reciprocal overlapping. The dimensions that have been included in this study figure in bold. The reference model is on the left.

Table 2
Descriptive statistics.

Construct	All schools	General education	Full-time vocational education	Dual vocational education
Passive technology use	4.07 (1.03)	3.87 (1.10)	**4.23** (1.12)	4.18 (.95)
Active technology use	3.39 (1.24)	3.21 (1.29)	3.47 (1.24)	**3.52** (1.17)
Constructive technology use	3.09 (1.14)	2.83 (1.13)	2.98 (1.23)	**3.31** (1.08)
Interactive technology use	2.67 (1.19)	2.40 (1.08)	2.50 (1.27)	**2.89** (1.21)
Teachers` positive beliefs	3.44 (.96)	3.33 (.98)	3.39 (.86)	**3.52** (.95)
Teachers` TK	3.24 (1.02)	3.21 (1.07)	**3.35** (.82)	3.28 (1.00)
Teachers` TPCK	3.97 (.80)	3.98 (.81)	**4.06** (.87)	3.95 (.80)
Informal collaboration	2.66 (.98)	2.55 (.94)	2.34 (1.04)	**2.76** (1.00)
Formal collaboration	3.01 (1.05)	2.84 (1.02)	2.75 (.95)	**3.12** (1.05)
ICT importance	3.62 (.96)	3.53 (.92)	3.54 (.91)	**3.69** (.99)
Goal clarity	3.05 (1.01)	2.88 (.96)	2.81 (1.03)	**3.15** (1.03)
Leader support	3.92 (.88)	3.87 (.82)	3.68 (.92)	**3.94** (.92)

Note. Means and standard deviations (in brackets) are weighted. Per each construct, the highest mean across school-types is in bold.

equipment and infrastructure at school. As is often the case, the tool component can be negligible in technologically developed countries (Schmitz et al., 2022). The pedagogy aspect, a recent extension of the model (Knezek & Christensen, 2016; Petko, 2012), captures the teaching style and related instructional strategies.

In technology integration, pedagogy also includes "the level of confidence teachers feel in their use of instructional strategies for technologies to enhance learning for their students" (Knezek & Christensen, 2016, p. 312) and, thus, is sometimes associated with the TPACK framework (Koehler et al., 2014; Mishra & Koehler, 2006). TPACK identifies knowledge domains that are necessary for effective technology integration, starting with the three main knowledge areas: technological knowledge (TK), related to the use of technology; pedagogical knowledge (PK), related to pedagogy and teaching methods and processes; and content knowledge (CK), related to disciplinary content. Four additional components can be extracted from the combination of the previous ones (PCK, TCK, TPK, and TPCK), with technological pedagogical content knowledge (TPCK) as the resulting core of the framework. Although it is evident that the framework is centred on teacher's knowledge, progressively, the role of context has been increasingly considered as a fundamental component of the framework itself (Rosenberg & Koehler, 2015), further highlighting the importance of considering personal and school-related factors at the same time. Knezek and Christensen (2016) explicitly mentioned TPACK with regard to the pedagogy component, and several studies have also operationalised the WSTP model using scales grounded on the TPACK model (e.g. Farjon et al., 2019; Guggemos & Seufert, 2021; Schmitz et al., 2024).

Based on this introduction, we can easily identify some overlapping and parallelisms across well-acknowledged models related to the personal and school-related factors we introduced so far (see Table 1 for an overview). Comparing the TAM and EVT, for example, Ranellucci et al. (2020) highlighted a clear example of a jangle fallacy—the reference to the same construct by using two differently labelled measures (Gonzalez et al., 2021). Similarly, Lachner et al. (2024) referred to jangle fallacies when considering the overlap between TPACK, self-efficacy, and beliefs. For example, at the personal level, value beliefs are constituents of the EVT, the TAM (mirrored, *inter alia*, in constructs such as perceived usefulness and attitude towards technology), and the WSTP model (considering the 'will' component in particular). Similarly, concerning ability beliefs, the 'pedagogy' component in the WSTP model generally corresponds to the TPCK component of the TPACK framework, and TK—although a kind of knowledge—is sometimes used by scholars to operationalise the 'skill' component of the WSTP model (e.g. in Farjon et al., 2019; Guggemos & Seufert, 2021; Schmitz et al., 2024).

Similarly, both the TAM—especially in its further versions, such as the unified theory of acceptance and use of technology (UTAUT; Venkatesh et al., 2003)—and the WSTP model also consider factors that go beyond personal factors to include school-related factors. School-related factors have sometimes been identified under the label of 'school readiness' by WSTP scholars (e.g. Christensen & Knezek, 2017; Petko et al., 2018), including aspects that correspond to the institutional first-order barriers in the 'barrier to technology integration' model (Ertmer, 1999). Given that the WSTP model seems to cover all the aspects that are also covered by the other considered models, we took it as our main reference and therefore placed it on the leftmost column of Table 1. The other columns thus mainly reference the first column and not necessarily each other directly.

To end this section, we briefly comment on the interplay between personal and school-related factors. Although recent research has shown that personal factors weigh more than school-related ones regarding

Table 3
Bivariate correlations of personal and school-related factors.

	Positive beliefs	Formal collaboration	Informal collaboration	Goal clarity	Leader support	ICT importance	TK	TPCK	Passive tech. use	Active tech. use	Constructive tech. use	Interactive tech. use
Positive beliefs	1	.134[a]	.168[a]	.257[a]	.148[a]	.167[a]	.289[a]	.400[a]	.374[a]	.306[a]	.352[a]	.337[a]
Formal collaboration	.134[a]	1	.568[a]	.512[a]	.533[a]	.581[a]	.158[a]	.160[a]	.128[a]	.177[a]	.217[a]	.192[a]
Informal collaboration	.168[a]	.568[a]	1	.548[a]	.467[a]	.570[a]	.275[a]	.226[a]	.151[a]	.206[a]	.254[a]	.254[a]
Goal clarity	.257[a]	.512[a]	.548[a]	1	.620[a]	.609[a]	.195[a]	.249[a]	.197[a]	.239[a]	.289[a]	.252[a]
Leader support	.148[a]	.533[a]	.467[a]	.620[a]	1	.682[a]	.080[a]	.205[a]	.148[a]	.179[a]	.198[a]	.174[a]
ICT importance	.167[a]	.581[a]	.570[a]	.609[a]	.682[a]	1	.169[a]	.240[a]	.208[a]	.289[a]	.266[a]	.213[a]
TK	.289[a]	.158[a]	.275[a]	.195[a]	.080[a]	.169[a]	1	.414[a]	.274[a]	.249[a]	.282[a]	.259[a]
TPCK	.400[a]	.160[a]	.226[a]	.249[a]	.205[a]	.240[a]	.414[a]	1	.351[a]	.313[a]	.338[a]	.283[a]
Passive technology use	.374[a]	.128[a]	.151[a]	.197[a]	.148[a]	.208[a]	.274[a]	.351[a]	1	.552[a]	.497[a]	.435[a]
Active technology use	.306[a]	.177[a]	.206[a]	.239[a]	.179[a]	.289[a]	.249[a]	.313[a]	.552[a]	1	.722[a]	.606[a]
Constructive technology use	.352[a]	.217[a]	.254[a]	.289[a]	.198[a]	.266[a]	.282[a]	.338[a]	.497[a]	.722[a]	1	.810[a]
Interactive technology use	.337[a]	.192[a]	.254[a]	.252[a]	.174[a]	.213[a]	.259[a]	.283[a]	.435[a]	.606[a]	.810[a]	1

Note.
[a] $p < .001$.

teachers' technology integration (e.g. Cattaneo et al., 2022; Lucas et al., 2021), the latter should be considered a necessary condition for technology integration. For example, without a proper infrastructure (i.e. computers and internet connection), many teaching and learning activities would not be possible. Some studies have also shown that technology integration depends on individual teachers' characteristics, but this is, in turn, influenced by school-related factors. From this perspective, individual factors therefore mediate the role of school-related factors in technology integration (e.g. Petko et al., 2018).

1.2. *Effects of personal and school-related factors: quality of technology integration*

Once the main factors involved in technology integration have been clarified, it is worth questioning how the outputs of this integration have been investigated. This section reports on this issue, starting from the consideration that recent literature not only analyses the frequency of technology use but has increasingly focused on the quality of this integration, for which we introduce the interactive-constructive-active-passive (ICAP) model.

According to Consoli et al. (2023), studying technology integration in educational settings typically involves "the use of technology in educational contexts to support educational goals" or "the process leading to that" (p. 16). These are often studied through the lenses of the above-mentioned factors, and the output measures are typically operationalised in two different ways, depending on whether scholars are more interested in the quantity or in the quality of integration. In the former case, the most common indicator in almost all large-scale studies was the frequency of technology use at school. For example, in the Trends in International Mathematics and Science Study (TIMSS), the Programme for International Student Assessment (PISA) (e.g. the ICT familiarity questionnaire 2018[1]), and the ICILS (e.g. the student questionnaire for the 2018 main study[2]), many questions start with "How often do you use ICT/digital devices for … ?" (Backfisch et al., 2021; Petko et al., 2016).

Although recently the debate has been partially reopened (OECD, 2023), over the years scholars have started to question the fact that simply using technology could be effective for getting learning results (e.g. Higgins et al., 2012; Tamim et al., 2011), and after the OECD (2015) publication, this awareness spread even more. Therefore, scholars are increasingly taking the quality of integration into consideration (Antonietti et al., 2023; Fütterer et al., 2022; Juuti et al., 2022; Lachner et al., 2024). The operationalisation of 'quality' varies across these studies. Some of them, for example, consider quality in relation to learners' cognitive activation, which teachers can promote using technology or digital tools with respect to specific pedagogical goals (Consoli et al., 2023).

In this direction, the ICAP model (Chi, 2009; Chi & Wylie, 2014) has often been used to study technology integration (e.g. Antonietti et al., 2023; Deepika et al., 2021; Ninković et al., 2023; Sailer et al., 2021; Wekerle et al., 2020), although it was not originally conceived for this purpose. The ICAP model refers to the kind of students' cognitive engagement that different learning activities can prompt, distinguishing between four different and incremental cases. Passive learning activities involve students engaging with knowledge in a receptive manner; here, the students do not manipulate or interact with the learning materials. Interaction, on the contrary, characterises active learning activities. As a step further, constructive learning activities subsume interaction, but they also add the assumption that students create new knowledge that goes beyond the received materials and information. Finally, interactive learning activities assume that learners collaboratively create new knowledge. Each of these cases implies cognitive processes (namely storing, integrating, inferring, and co-inferring) that lead to building knowledge structures. As the four kinds of learning activities are

[1] https://www.oecd.org/pisa/data/2018database/CY7_201710_QST_MS_ICQ_NoNotes_final.pdf.

[2] https://nces.ed.gov/surveys/icils/pdf/ICILS-2018-MS-StudentQuest-US.pdf.

conceived incrementally, progressively moving from passive to active to constructive to interactive also implies that these processes cumulate: If passive learning activities foresee mainly storing processes, active learning activities add linking to storing, constructive learning activities additionally foresee inferring, and finally co-inferring is also characterising interactive learning activities. For these reasons, the ICAP model also assumes that the higher the level of the learning activity, the better and more profound the learning outcomes. Scholars usually report interactive and constructive technology-supported learning activities as requiring deep learning processes and leading to higher student learning achievements than passive and active technology-supported learning activities, requiring only shallow learning processes (Chi et al., 2018; Stegmann, 2020). Considering the quality of technology integration through the ICAP model can also constitute a first attempt to assess the process over the product (Kopcha et al., 2020) and to differentiate between teacher-centred (passive) and student-centred (active, constructive, and interactive) technology-supported activities.

1.3. Upper secondary level education: differentiating between general and vocational education

Although the factors and effects of technology integration have been widely studied across various educational levels, they remain underexplored at the upper secondary level. This section outlines the main characteristics of this stage, differentiating between general and vocational education, before providing a closer look at the specific context of this study.

At the upper secondary level, several educational systems distinguish between general education and vocational education and training (VET). Depending on the context and the national systems, VET can also be referred to using different labels, such as 'technical education' or 'career and technical education' (Guile & Unwin, 2019a). For various reasons, 'the dominance of systems-based approach has meant that in much of the international research literature on education, VET has been separated from and positioned below "higher education"' (Guile & Unwin, 2019b, p. 2). However, given the direct relationship that VET has with economy and productivity, as well as its explicit orientation towards the development of skills and professional competences, many governments are supporting the development of dual VET systems, and 'greater attention is being paid to the measurement of VET performance in the economic literature' (ivi, p. 9). Several VET systems in Europe are organised as 'dual systems' or 'dual-track apprenticeship', in which the curriculum is based on a combination of practical-oriented apprenticeship in a company and theory-oriented classroom instruction in a vocational school. From a political and economic perspective, VET is perceived as an important opportunity because international statistics show that in countries where a VET system exists (either in its dual form such as in Switzerland, Germany, Austria, Lichtenstein, Netherlands, and Denmark or in other forms such as in Sweden and Finland), the rate of adolescence and adult unemployment is distinctively lower, poverty risk is lower, migrant integration is more effective than in other countries, the workforce is highly qualified, and companies are competitive, efficient, and innovative (Strahm et al., 2016). Moreover, vocational education is crucial for the economy in the short term, whereas general education becomes so in the long term (Asadullah & Zafar Ullah, 2018; Muehlemann, 2019; Nilsson, 2010). All these reasons make VET worthy of further investigation (Seifried, 2023), and its comparison with general education is an interesting endeavour for understanding the specific respective peculiarities.

Furthermore, in the Swiss context, in which our study was conducted, there are important differences between the two orientations: In general education (including baccalaureate schools and upper secondary specialised schools), the curriculum is strongly oriented towards academic knowledge, subject-based, and learners—implicitly considered more gifted than those attending vocational education to reach academic goals—attend full-time schools, usually for four years. In cases where the curriculum lasts three years, preparatory baccalaureate education is compulsory during the last year of lower secondary education (IDES, 2022). By contrast, VET schools—a programme chosen by two-thirds of upper secondary school pupils (SERI, 2022)—are mostly based on a dual track (Bonoli et al., 2018; Deissinger & Gonon, 2021; Strahm et al., 2016; Wettstein et al., 2017), are much more driven by experience-based, practical learning, and are less oriented towards a unique academic goal. Depending on the selected profession (about 250), apprentices spend one or two days per week at school and the rest of the week at the workplace, working under the supervision of an in-company trainer and receiving a salary. A third learning location has also emerged since 2002, where branch courses coordinated by the professional association take place. However, in some professions, VET schools also present the possibility of choosing a full-time school-based curriculum, proposing an organisational structure that is more similar to the one that general education adopts; in this case, practical laboratory activities take place within the school context and replace the work-based segment. Apart from two-year programmes providing a federal VET certificate, VET programmes last three or four years, depending on the profession, and lead to a federal VET diploma. Learners can also choose to obtain a federal vocational baccalaureate either during their training or after getting a VET diploma. The baccalaureate title gives them the possibility of enrolling in a university of applied sciences.

These distinctions are relevant because of the potential assumption that such considerable organisational differences may influence the way technology is integrated into the curriculum and because teacher training—despite being nationally recognised—is organised regionally by different institutions and leads to different qualifications depending on the teachers' profiles. Teachers in general education usually receive a subject-based academic degree and add a pedagogical further education, including internships and practical training (Criblez, 2001, 2014, 2016; Eberle, 2019). Most VET teachers, by contrast, first learn a profession and work some years in industry or services before entering a specific vocationally oriented teacher training programme (Novak, 2018). Regarding the specificities of digital competences, for example, the teacher training plan for baccalaureate schools and high schools in the Italian-speaking region—explicitly inspired by the same plan adopted in the French-speaking area—includes a module dedicated to 'Information and communication technologies and teaching,' corresponding to 4 ECTS.[3] The exit competence profile for these teachers consists of 10 competences, the last of which is 'Using information and communication technologies to prepare and conduct teaching/learning activities and to manage teaching and professional development' (SUPSI, 2024). Similarly, one of the 17 competences envisaged in the 2022 profile by one of the largest teacher training colleges for upper secondary teachers in the German-speaking area refers to 'integrating digitalisation', although there does not appear to be a module dedicated to this competence in the curriculum (PH Bern, 2021). For VET teachers working in school for more than 50% of their working time, there are no differences between being active in a dual track or being in full-time schools. Similar to general education, they also attend a 4-ECTS module dedicated to technology integration in teaching and learning activities.

1.4. Aims and research questions

We have underlined the importance of VET and the structural differences in how the curriculum is organised with respect to general education, and we have seen that concerning technology integration, teachers are trained on a similar basis. We know that personal and

[3] ECTS stands for European Credit Transfer and Accumulation System. It is a standard means to value and then compare academic credits across European countries. Usually, 60 ECTS credits correspond to a full academic year, and is equivalent to 1500–1800 h of total workload.

school-related factors determine the effectiveness of technology integration. However, little attention has been paid to the differential contribution of the same factors to integration based on changes in the quality of integration and considering the structural differences between general and vocational education. Therefore, this study aims to investigate the extent to which personal and school-related factors relate to the quality of technology integration in teaching at the upper secondary level and particularly how this differs depending on the school type, which is then considered as an additional predictor.

We should immediately clarify that although this cross-sectional study does not allow us to infer causal inferences and only correlations are checked in the following analysis, here and in the results section, we use the term "predictor" (and the related verb) as a technical term indicating a correlation between two variables. Similarly, by "effects", we do not mean to subsume a real cause–effect relationship but only a statistical correlation, although in the model tested, a direction is implicitly assumed.

Our main research questions are: Is there a difference between general and vocational education in the quality of technology integration by teachers? Do personal and school-related factors play different roles in determining this difference in general and vocational education? More specifically, considering that the effect of school-related factors is often mediated by personal factors (Petko et al., 2018), we investigate the direct effects of personal and school-related factors on technology integration, as well as the direct effects of school-related factors on personal factors (for more details, see Section 2.3). Given that very few studies have compared different school types within the upper secondary level, we do not formulate specific hypotheses to test the differences across school types and, therefore, consider this study exploratory in nature.

Within personal factors, we include TK, TPCK, and teachers' beliefs about the role educational technologies play in supporting learning (see Table 1). We also considered general personal characteristics such as gender, age, and years of teaching experience, which yielded mixed evidence across previous studies (as reported, for example, in Cattaneo et al., 2022; Cheng & Xie, 2018; Lucas et al., 2021; Tondeur et al., 2008). School-related factors include opportunities for formal and informal collaboration, the importance technologies have for the school, goal clarity about technology integration, and the presence of leadership support. The quality of technology integration is measured in terms of different activities supported by technology, according to the ICAP model.

Finally, we compare three types of schools: general education (or baccalaureate schools), vocational education schools ending with a federal VET diploma (dual track), and vocational schools providing a federal vocational baccalaureate (full-time track). The last programme completes the federal VET diploma curriculum with further general education and entitles students to enrol in a university of applied sciences, thus configuring itself as a hybrid of classic dual VET and general education programmes.

2. Methods

2.1. Participants

Data collection was performed through a self-administered web survey distributed to all teachers active in the second and third years of 526 upper secondary schools in Switzerland in two separate waves. A first wave was planned for the Zürich Canton from September 20 to November 8, 2021; a second wave was then distributed to all the other Swiss Cantons from May 1 to August 1, 2022. Participation was voluntary. Overall, 2248 teachers from 113 schools participated in our survey. Given our aim of comparing teachers teaching in dual vocational education schools, full-time vocational schools, and general education schools, we removed those who teach in more than one of the three tracks. This led to a final analytical sample of 1660 teachers from 106 schools.

Regarding gender, 51.1% of our sample identified as male, 46.6% as female, and 2.2% chose the category 'other' to describe their gender. The mean age was 46.7 years (SD = 9.8), and the mean number of years of teaching experience was 15.8 years (SD = 9.6). In terms of school type, 53.6% were teaching in baccalaureate schools, 38.1% were teaching in dual vocational education schools, and 8.3% were teaching in full-time vocational education schools. Regarding the language region, 82.1% of the teachers were located in the German-speaking part of Switzerland, 7.0% were employed in schools in the French part of Switzerland, and 10.9% were working in schools in its Italian-speaking region.

2.2. Measures

2.2.1. Personal (teacher-related) factors

The teacher-related factors in this study encompassed teachers' beliefs and self-reported knowledge according to the TPACK framework. Teachers' *positive beliefs* about digital technologies in teaching and learning were measured using the scale developed by Petko et al. (2018). Teachers were asked to show their agreement with statements about the potential positive effects of using technologies in class (four items, e.g. "Students' performance can be improved if digital technologies are used"). The teachers' positive beliefs had a McDonald's omega of .90.

Regarding teachers' *self-reported knowledge* based on the TPACK framework, TK and TPCK were selected for this study following Schmid et al. (2020) (three items, e.g. "I keep up with important new technologies" for TK; and three items, e.g. "I can use strategies that combine content, technologies, and teaching approaches" for TPCK). Whereas TK had a McDonald's omega of .86, TPCK had a McDonald's omega of .87.

The answer options for all the scales concerning personal factors ranged from 1 (*totally disagree*) to 5 (*totally agree*).

2.2.2. School-related factors

For school-related factors, the main constructs of school readiness for technology integration and their measurements by Petko et al. (2018) were chosen, except for the quality of the digital infrastructure, which has been ruled out as a significant predictor of technology integration in high-tech countries such as Switzerland (Petko & Prasse, 2018; Schmitz et al., 2022, 2023).

We used several constructs to measure school readiness for technology integration. *Formal collaboration* (three items, e.g. "It often happens that we organise internal school information events on the topic of the use of digital technologies in class"), which had a McDonald's omega of .81. *Informal collaboration* (four items, e.g. "We have very intensive discussions about our experiences regarding the possible uses of digital technology"), which showed a McDonald's omega of .78. The *importance of ICT in school strategy* (three items, e.g. "The topic of digitalisation is very important at our school"), having a McDonald's omega of .81. *Goal clarity* regarding digital technologies (three items, e.g. "I am very clear about my school's goals for the use of digital technologies"), which had a McDonald's omega of .77. *Leadership* support regarding digital technologies (three items, e.g. "Colleagues with new ideas for the use of digital technologies are actively supported by the school leader"), which exhibited a McDonald's omega of .79. The answer options for all the scales concerning school-related factors ranged from 1 *(totally disagree)* to 5 *(totally agree)*.

Furthermore, the school type was investigated. The teachers were divided into three groups—dual vocational education schools, full-time vocational education schools, and general education baccalaureate schools—based on their self-reports about where they taught.

2.2.3. Technology integration

To measure the *quality* of technology integration—that is, for the different types of learning activities according to the ICAP model—the scales of the ICAP Technology Scale (ICAP-TS) were selected (Antonietti et al., 2023). The passive technology use subscale consists of three items describing teachers using digital technologies while students remain receptive (e.g. "For which teaching and learning activities do you use digital technologies? To inform about learning objectives and content"). For this subscale, the McDonald's omega was .87. The active technology use subscale with three items covers technology use by students to apply previously acquired knowledge to simple exercises (e.g. "For which learning activities do your learners/students use digital media in your lessons? So that they actively repeat and practice the knowledge imparted"). For this subscale, the McDonald's omega was .90. By contrast, the constructive technology use subscale contains three items mirroring students' use of digital technologies to acquire new knowledge individually (e.g. "For which learning activities do your learners/students use digital media in your lessons so that they can acquire new knowledge individually?"). Regarding this subscale, the McDonald's omega was .88. Finally, the subscale interactive technology use encompassing three items focuses on students' use of technology with their peers to acquire new knowledge together (e.g. "For which learning activities do your learners/students use digital media in your lessons? So that they develop new knowledge together with others"). This subscale had a McDonald's omega of .91. The answer options for the scales of the ICAP-TS ranged from 1 *(almost never)* to 5 *(almost every lesson)*.

2.3. Statistical analysis

2.3.1. Descriptive statistics

For descriptive statistics, the means and standard deviations were calculated for all constructs of the survey. For all descriptive statistics, sampling weights were calculated and applied to the data according to the following formula to account for the slightly distorted distribution concerning participants per school, school type, and language region (Meinck, 2015; Schmitz et al., 2023): Weight = a(N of teachers who taught in the school/N of respondents in the school)*b(N of teachers in a language region/N of respondents in a language region)*c(N of teachers teaching in a school type/N of respondents in a school type)*(Mean (a*b*c))

Since weighted data lead to distorted results of regression analyses and can then lead to misinterpretation, unweighted data were used for all inferential statistics (Gelmann, 2007; Winship & Radbill, 1994). The weighted descriptive statistics were calculated using SPSS.

2.3.2. Inferential statistics

Petko et al. (2018) showed that teacher-related factors mediate the relationship between school-related factors and technology integration. However, we did not have enough clusters (schools) to perform multilevel structural equation modelling (SEM) mediation with several mediators (McNeish, 2017). Consequently, we conducted SEM with cluster-robust standard errors to account for the fact that teachers are nested in schools (see Oberski, 2014; Stapleton et al., 2016). This approach also fits the idea that our data are entirely based on the individual perceptions of teachers. For each of the models, the goodness of fit was evaluated considering the values for the TLI and the CFI >.95 as good and the values for the RSMEA and the SRMR <.08 as a good fit (Brown, 2015; Hu & Bentler, 1999). Since we have cross-sectional data, performing mediation would be problematic for the interpretation of the data (Maxwell & Cole, 2007). Thus, we performed SEM with cluster-robust standard errors to separately examine the three relationships we expected in the mediation model (Petko et al., 2018): (1) the relationship between school-related factors and technology integration, (2) the relationship between school-related factors and personal factors, and (3) the relationship between personal factors and technology integration. For the models involving school-related factors, we performed several modifications, allowing residual covariances between the items of the school-related factors to improve the model fit. These residual correlations can be theoretically justified, as Petko et al. (2018) showed that school-related factors are statistically and conceptually closely related to each other, and in the structural equation model, these latent variables also load onto one overarching factor. However, since we aimed to investigate more closely the differential effects of the school-related factors on personal factors and technology integration, we did not add the overarching factor to the model but instead allowed residual covariances between the items of the school-related factors. Thus, in line with the methodological literature, we only allowed for residual covariances between items based on a solid theoretical assumption (see Brown, 2015). The separate SEM analyses instead of the mediation model opened up the possibility of examining the individual relationship between the different personal (teacher-) and school-related factors in more detail, which could not be considered in Petko et al.'s (2018) mediation model due to the limited sample size.

In terms of school-related factors, the school type distinguishing between general education, dual vocational education, and full-time vocational education was dummy coded with the general education schools as the reference category. Regarding the models investigating the relationship between personal factors and technology integration, gender (dummy-coded with male as a reference category), age and number of teaching years were added as control variables. The analyses were conducted using the open-access software R with the package lavaan.

3. Results

3.1. Descriptive statistics

Table 2 shows substantial variations in the indicators of technology integration and teacher-related factors, which were explained by subsequent analyses. Regarding the subscales of the ICAP-TS, teachers reported the highest frequency of technology integration for passive technology use and the lowest frequency for interactive technology use. For teacher-related factors, the highest mean was reported for TPCK and the lowest for TK. For school-related factors, the highest mean was reported for school leader support regarding digital technologies, whereas the lowest mean was reported for informal collaboration regarding digital technologies. Comparing the different school types, we observed that full-time vocational education and dual vocational education teachers reported slightly higher levels of the different indicators of technology integration. Bivariate correlations between the variables

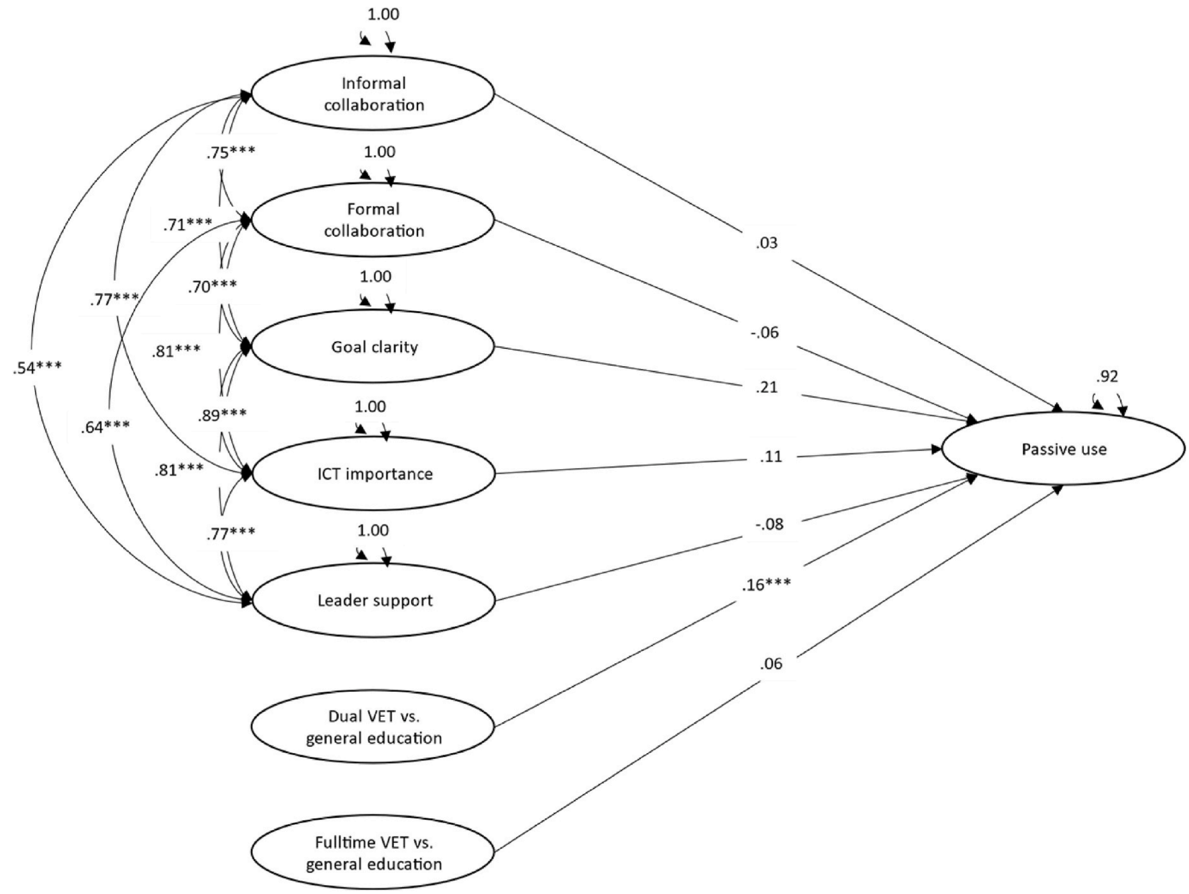

Fig. 1. Relationship between school-related factors and passive use.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

reported in Table 2 are provided in Table 3.

3.2. *Structural equation modelling with cluster-robust standard errors*

3.2.1. *The relationship between school-related factors and technology integration*

After 15 modifications allowing for the items to covariate with each other, the fit for the model investigating the relationship between school-related factors and passive use was considered good (χ^2 (139) = 527.746; $p < .001$; TLI = .953; CFI = .966; RMSEA = .048; SRMR = .043). All factor loadings of the constructs concerning school-related factors and passive use were greater or close to .60 and can be categorised as strong, according to Garson (2009). The R-squared was .08, indicating that 8% of the variance in passive use could be explained by the other variables of the model. Fig. 1 shows that none of the school-related factors was a significant predictor, except for school type. Teachers from dual vocational education used digital technologies significantly more often to foster students' passive learning activities than general education teachers. However, when dual vocational education was used as a reference category, there was no significant difference between the teachers from full-time and dual vocational education (β = −.03, p = .270).

In terms of active use, the model fit was evaluated as good after 13 modifications (χ^2 (141) = 531.960; $p < .001$; TLI = .954; CFI = .966; RMSEA = .048; SRMR = .042). Regarding the factor loadings of the school-related factors and active use, they were >.60 and can be considered as strong (see Garson, 2009). Regarding R-squared, 13% of the variance in active use could be explained by the other variables of the model. As depicted in Fig. 2, the importance of ICT in school strategy was a significant and positive predictor of promoting students' active learning activities. Moreover, teachers from full-time vocational education reported significantly higher levels of active use than teachers from general education. Using dual vocational education as a reference category revealed that teachers from full-time vocational education indicated significantly higher levels of active use than teachers from dual vocational education (β = .05, p = .048).

Regarding constructive technology use, the model again shows a good fit after 14 modifications, allowing for covariances between the items (χ^2 (140) = 522.189; $p < .001$; TLI = .953; CFI = .965; RMSEA = .048; SRMR = .041). In terms of the factor loadings concerning the latent constructs, they were >.60, which is strong (see Garson, 2009). The variance explanation for constructive technology use was 14%. As presented in Fig. 3, goal clarity regarding digital technologies is a significant and positive predictor of technology use for constructive learning activities. Furthermore, teachers from dual and full-time vocational education reported significantly higher levels of constructive use than teachers from general education. However, there was no significant difference between teachers from dual vocational education and full-time vocational education when dual vocational education was defined as the reference category (β = .03, p = .356).

Finally, the model fit for interactive use was evaluated as good after 12 modifications (χ^2 (142) = 561.039; $p < .001$; TLI = .953; CFI = .964; RMSEA = .049; SRMR = .042). Again, the factor loadings of the latent constructs concerning school-related factors and interactive use were >.60 and strong (see Garson, 2009). Concerning R-squared, 11% of the variance in interactive use could be explained by the variables of the

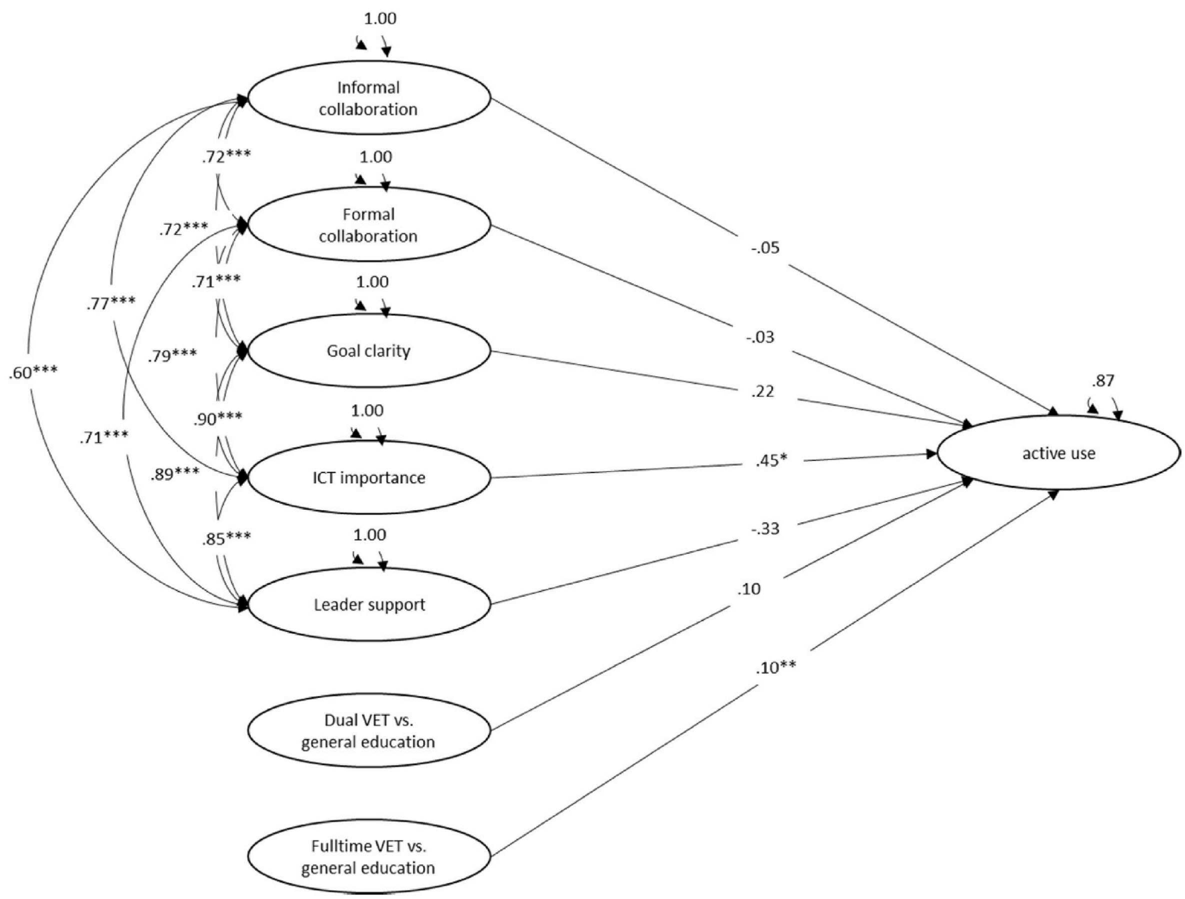

Fig. 2. Relationship between school-related factors and active use.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

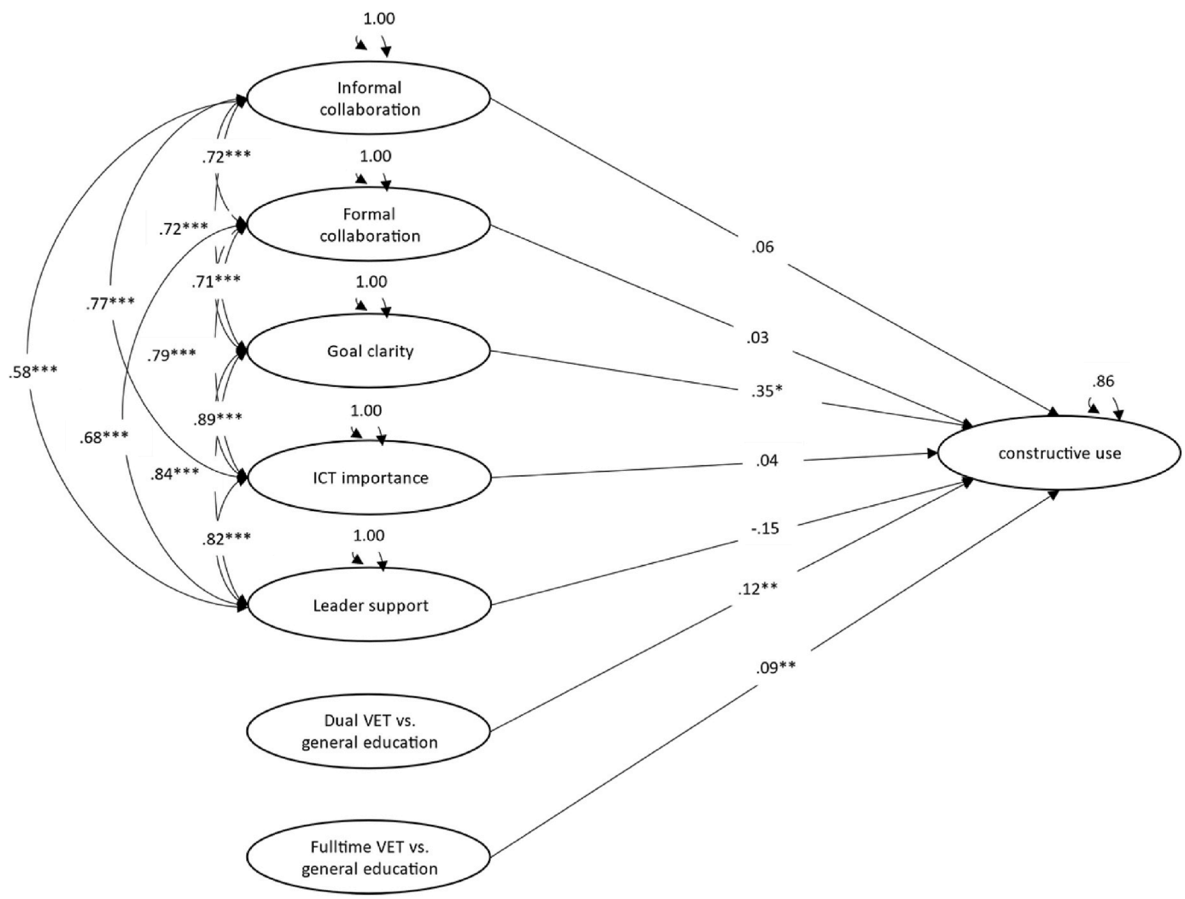

Fig. 3. Relationship between school-related factors and constructive use.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

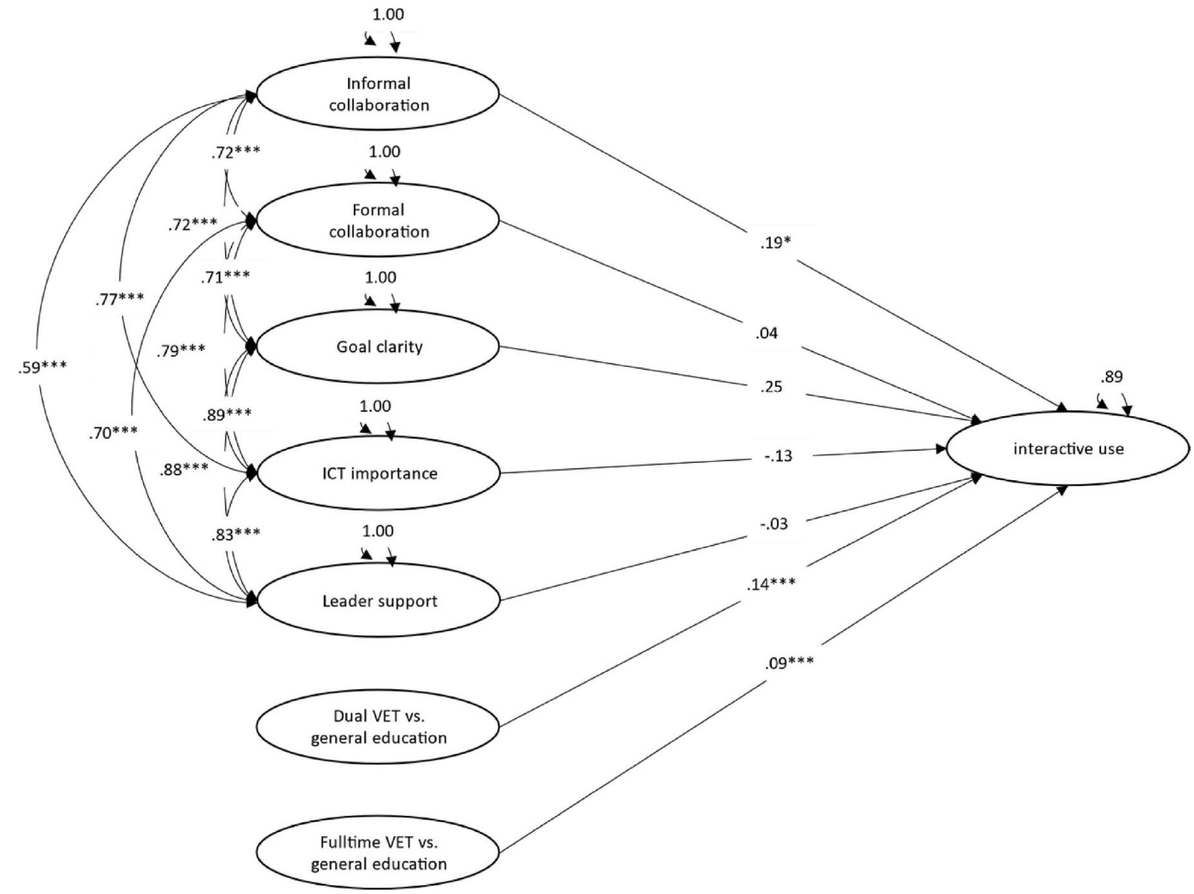

Fig. 4. Relationship between school-related factors and interactive use.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

model. As Fig. 4 reveals, informal collaboration was a significant and positive predictor of technology use to promote interactive learning activities. Similar to constructive use, teachers from dual and full-time vocational education reported higher levels of interactive use than teachers from general education. In line with the results of the model concerning constructive use, no significant difference was found between teachers from dual and full-time vocational education with dual vocational education as a reference category (β = .1, $p = .739$).

3.2.2. *The relationship between school-related factors and personal factors*

After 13 modifications, the model that investigated the relationship between school-related factors and teachers' positive beliefs regarding digital technologies showed a good fit (χ^2 (160) = 606.471; $p < .001$; TLI = .953; CFI = .964; RMSEA = .047; SRMR = .043). Concerning the factor loadings of the latent constructs related to school-related factors and teachers' positive beliefs regarding technology use in class, they were considered strong, at > .60 (see Garson, 2009). In terms of R-squared, 10% of the variance in positive beliefs could be explained by the variables of the model. As depicted in Fig. 5, goal clarity regarding digital technologies is a significant and positive predictor of teachers' positive beliefs regarding digital technologies in class. Furthermore, teachers from dual and full-time vocational education indicate significantly higher levels of positive beliefs towards digital technologies in class than general education teachers. However, there was no significant difference between teachers from dual and full-time vocational education when dual vocational education was defined as the reference category (β = .03, $p = .165$).

Similarly, after 12 modifications allowing covariances between items, the model examining the relationship between school-related factors and TK showed a good model fit (χ^2 (142) = 533.760; $p < .001$; TLI = .951; CFI = .963; RMSEA = .048; SRMR = .042) with strong factor loadings of the latent constructs, which were >.60 (see Garson, 2009). Moreover, 14% of the variance in TK could be explained by the variables of the model. Fig. 6 indicates that informal collaboration and goal clarity regarding digital technologies were significant and positive predictors of TK. However, leader support had a significant and negative effect on TK. Using general education or dual vocational education as a reference category for the dummy-coded school type variables revealed no significant differences between school types.

Regarding the relationship between school-related factors and TPCK, the model fit was good after 17 modifications, allowing for covariances between items (χ^2 (137) = 500.553; $p < .001$; TLI = .953; CFI = .966; RMSEA = .047; SRMR = .041). All the factor loadings of the latent constructs concerning school-related factors and TPCK were >.60 and were therefore strong (see Garson, 2009). In addition, 12% of the variance in TPCK could be explained by the variables of the model. The SEM analysis visualised in Fig. 7 indicates that goal clarity regarding digital technologies was a significant and positive predictor of TPCK. There are also significant differences concerning school type: teachers from dual and full-time vocational education reported significantly lower levels of TPCK than teachers from general education. However, with dual vocational education as a reference category, no significant difference was found between dual and full-time vocational education teachers (β = −.01, $p = .750$).

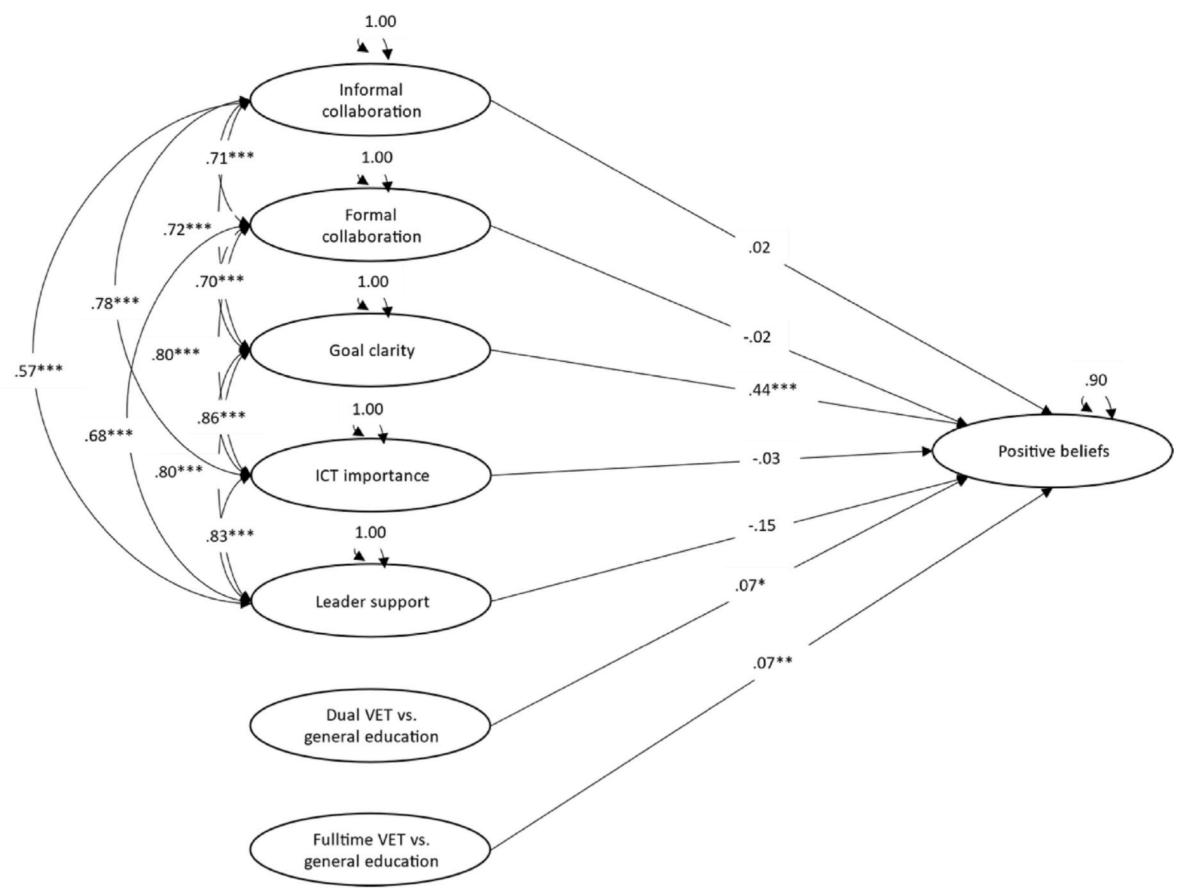

Fig. 5. Relationship between school-related factors and teachers' positive beliefs regarding digital technologies.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

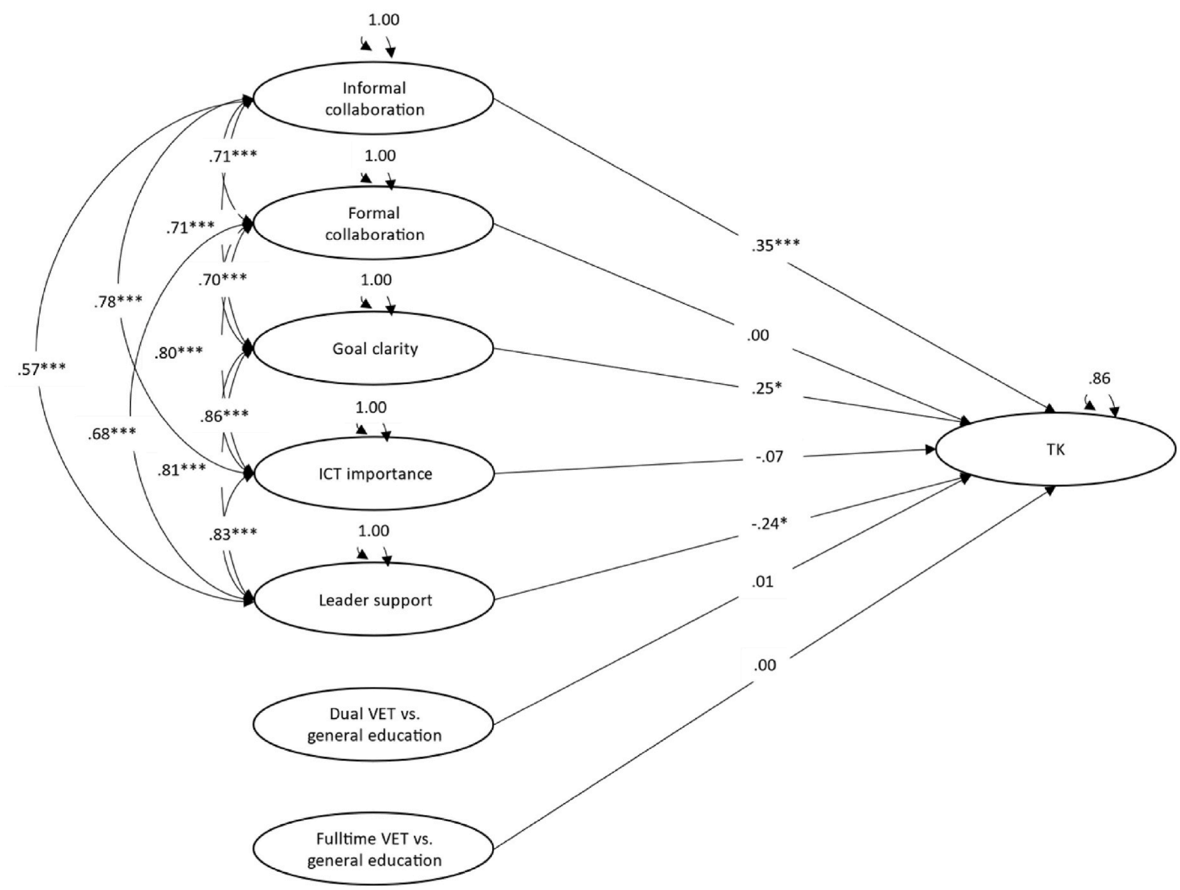

Fig. 6. Relationship between school-related factors and teachers' TK.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

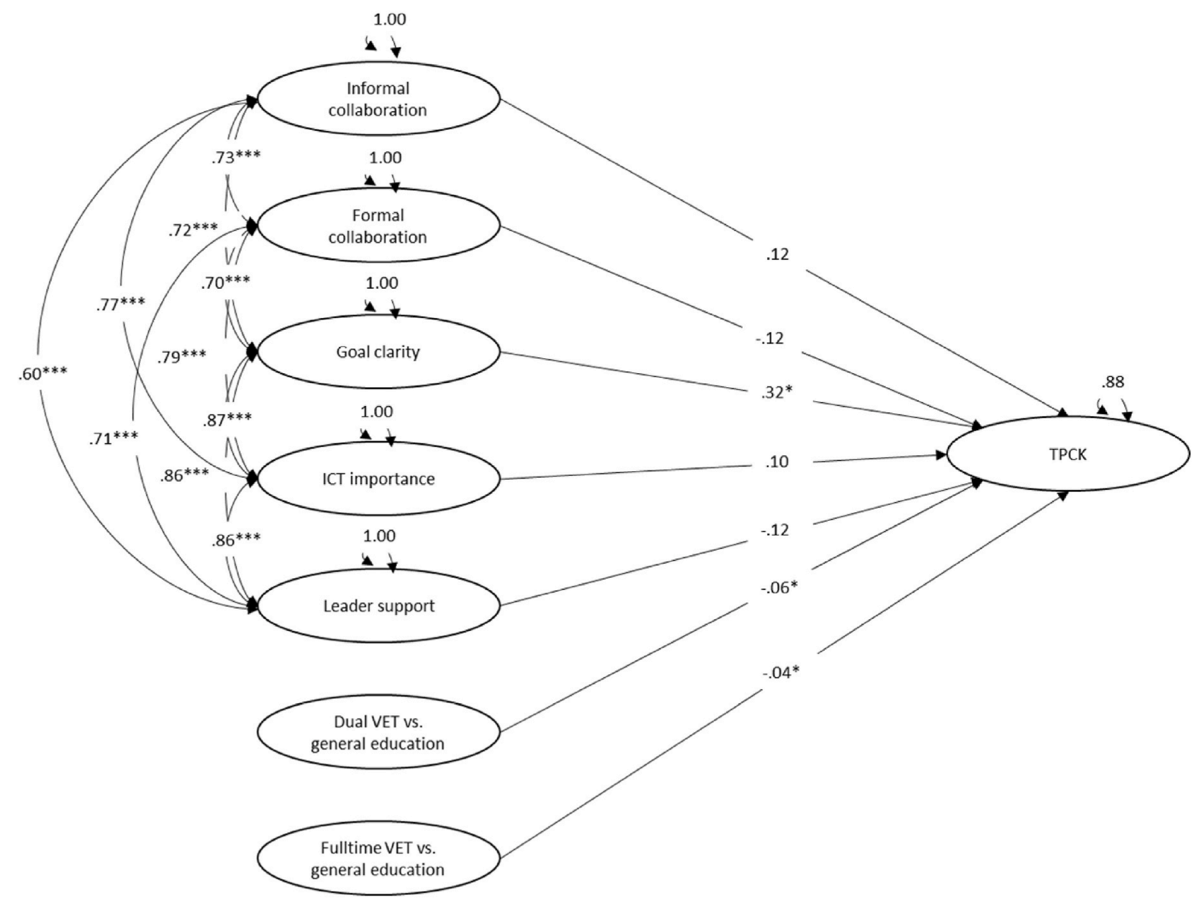

Fig. 7. Relationship between school-related factors and teachers' TPCK.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

3.2.3. The relationship between personal factors and technology integration

The model investigating the relationship between personal factors and passive use showed a good fit without any modification (χ^2 (107) = 559.806; $p < .001$; TLI = .951; CFI = .960; RMSEA = .055; SRMR = .054) and with strong factor loadings on the latent constructs, which were >.60 (see Garson, 2009). Regarding R-squared, 22% of the variance in passive use could be explained by the variables of the model. As depicted in Fig. 8, teachers' positive beliefs regarding digital technologies, their self-reported TK, and TPCK were significant and positive predictors of passive use. In addition, older teachers, and teachers with less experience tended to use digital technologies more often to promote passive learning activities. However, gender was not a significant predictor, with male or other as a reference category.

Similarly, the model examining the relationship between personal factors and active use showed a good model fit without any modification (χ^2 (107) = 520.599; $p < .001$; TLI = .957; CFI = .964; RMSEA = .052; SRMR = .050). Again, the factor loadings of the latent constructs were strong, at > .60 (Garson, 2009). The variance explanation for active use by the variables in the model was 18%. Fig. 9 indicates that teachers' positive beliefs regarding digital technologies, their self-reported TK, and TPCK were significant and positive predictors of technology use to support active learning activities, whereas age, teaching years, and gender (reference category male or other) were not significant predictors.

Again, no modifications were needed to ensure a good fit of the model that investigated the relationship between personal factors and constructive use (χ^2 (107) = 538.952; $p < .001$; TLI = .954; CFI = .962; RMSEA = .053; SRMR = .050), and the factor loading of the latent constructs was >.60. Overall, 22% of the variance in constructive use could be explained by the other variables of the model. In line with the previous models, teachers' positive beliefs and self-reported knowledge (TK and TPCK) were significant and positive predictors of technology use to promote constructive learning activities (see Fig. 10). Furthermore, female teachers reported significantly higher levels of constructive technology use than did male teachers. However, using other as a reference category for the dummy-coded gender variables, no significant difference between teachers identifying as female or other can be found ($\beta = .10$, $p = .287$).

Finally, the model examining the relationship between personal factors and interactive use showed a good model fit without any modifications (χ^2 (107) = 525.908; $p < .001$; TLI = .958; CFI = .965; RMSEA = .052; SRMR = .050) and with factor loadings for the latent constructs, at > .60. Regarding R-squared, 18% of the variance in interactive use could be explained by the other variables of the model. In line with the results of the previous models, Fig. 11 shows that teachers' positive beliefs and self-reported knowledge had a significant and positive effect on interactive use. Moreover, teachers with less teaching experience reported higher levels of interactive use compared to those with more

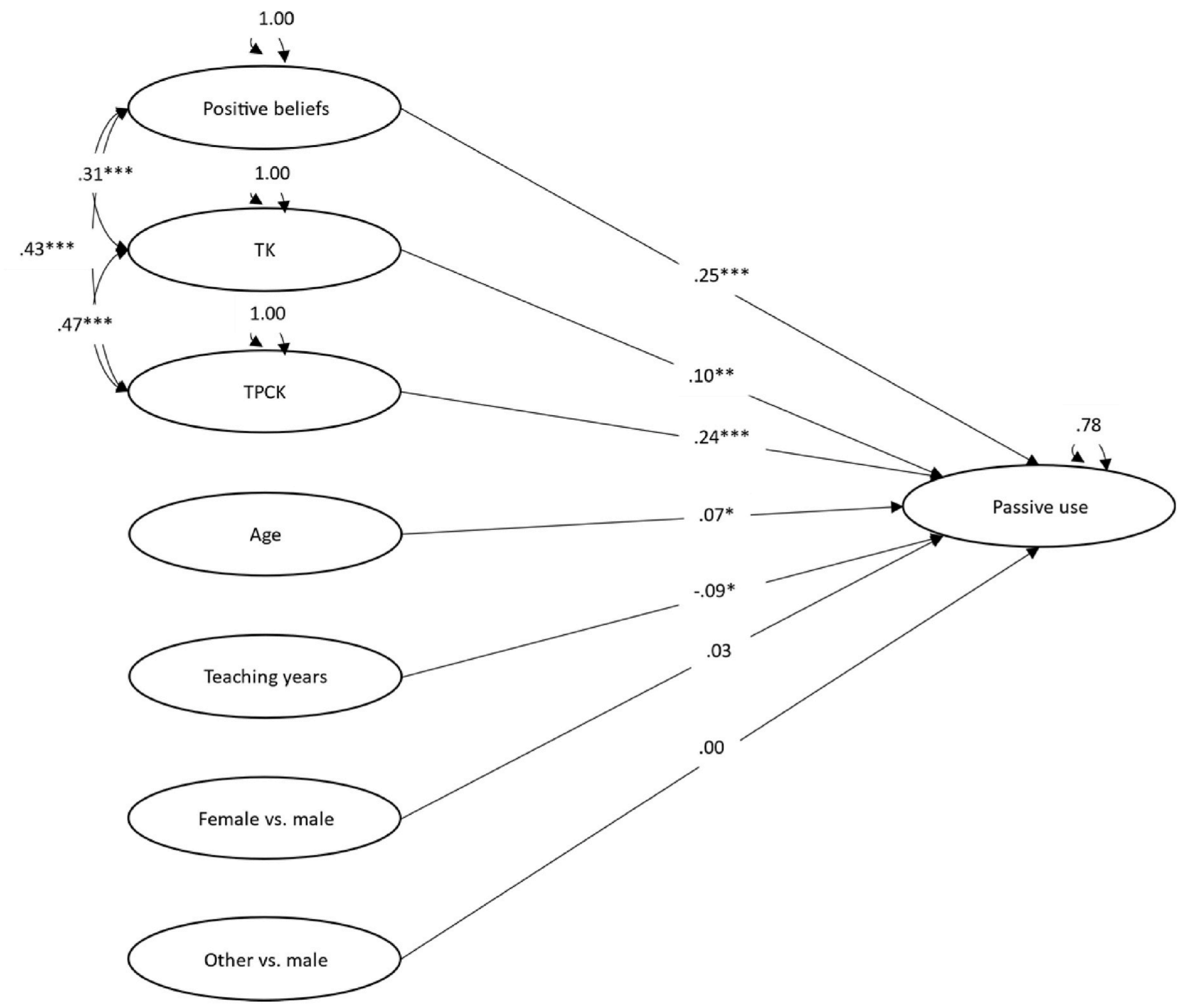

Fig. 8. Relationship between personal factors and passive use.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

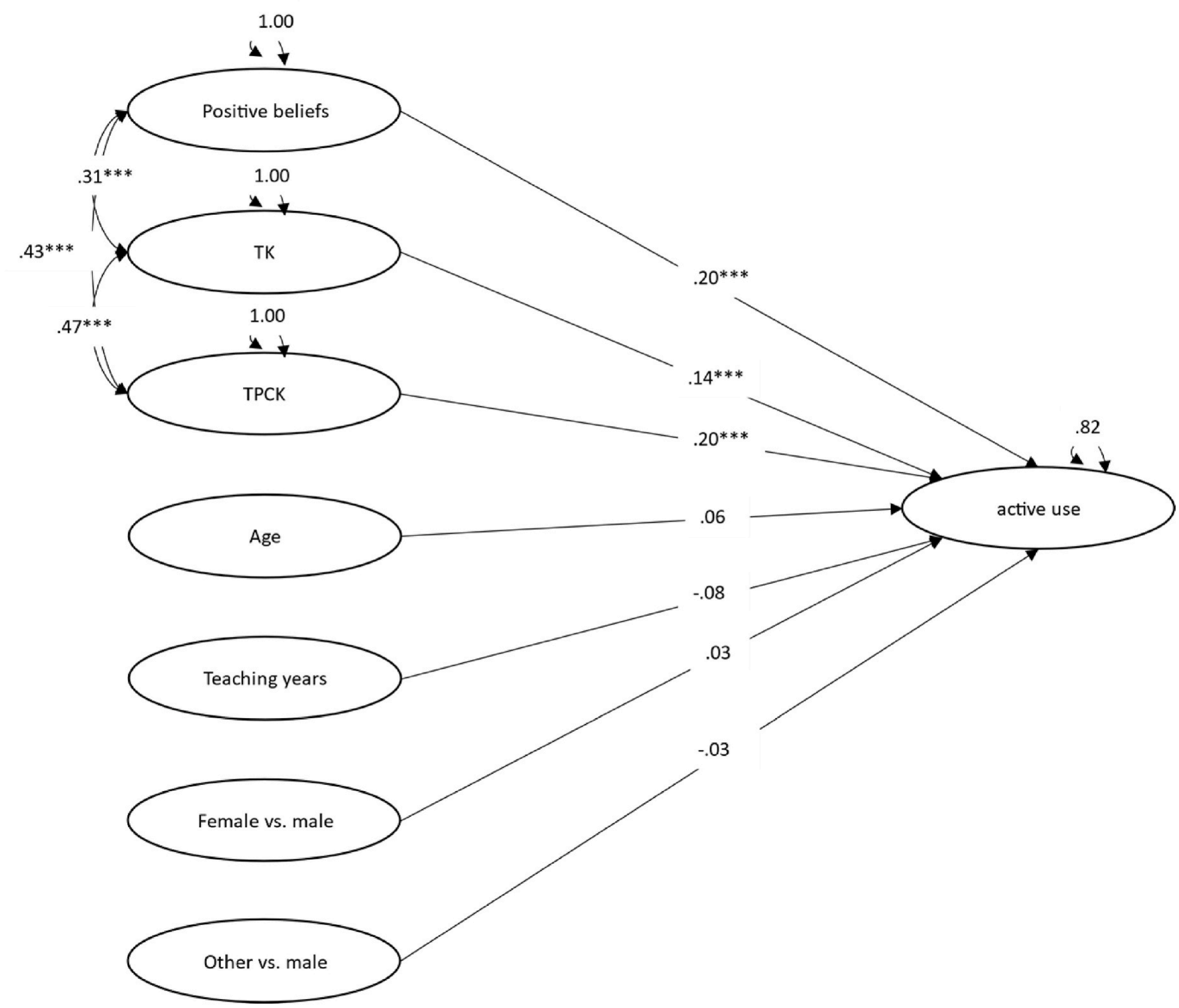

Fig. 9. Relationship between personal factors and active use.
Note. ***$p < .001$, **$p < .01$, *$p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

teaching experience, whereas age and gender (with male or other as a reference category for the dummy-coded variables) were not significant predictors.

For a concise overview of the results emerging from the SEM analysis reported in this section, Table 4 summarises the statistically significant relationships among the investigated factors.

4. Discussion

This study aimed to investigate the extent to which personal and school-related factors relate to the quality of technology integration in teaching at the upper secondary level and particularly how this differs based on the school type (general vs. vocational education), which was then considered an additional predictor. To answer these questions, we assessed our data using general descriptive statistics. We then performed SEM with cluster-robust standard errors to separately examine (1) the relationship between school-related factors and the quality of technology integration, (2) the relationship between school-related factors and personal factors, and (3) the relationship between personal factors and the quality of technology integration.

Overall, the descriptive statistics show that all school types at the upper secondary level in Switzerland exhibit high integration of technology in their teaching and learning activities. This could be due to government policies' emphasis on the need for digitalisation of the entire training system (Swiss Confederation, 2017a, 2017b, 2018; EDK-CDIP, 2018), particularly of vocational education (Schweri et al., 2018), at the end of the last decade. Examining the quality of technology integration, operationalised through the ICAP framework (Chi, 2009; Chi & Wylie, 2014), we observed that the higher the level of cognitive engagement required by students (i.e. moving from passive to active to constructive to interactive learning activities), the lower the frequency of technology use. Notably, vocational schools reported a more frequent use of technology than general education schools in all four types of activities. The difference between vocational and general schools in favour of the former aligns with previous results from both international (e.g. from the Teaching and Learning International Survey TALIS; OECD, 2019) and national studies (e.g. Antonietti et al., 2024). The same pattern, with vocational teachers presenting higher values than general education teachers, also shows up for the level of all the personal and school-related factors.

Regarding the relationship between school-related factors and the quality of technology integration, we observed only small significant relationships, with the importance of ICT in the school strategy acting as a predictor of active learning activities. This was particularly evident in full-time VET schools (significantly differing with respect to the other two school types). Furthermore, in both cases, goal clarity and informal collaboration constituted predictors of constructive and interactive learning activities, respectively, with significant differences between

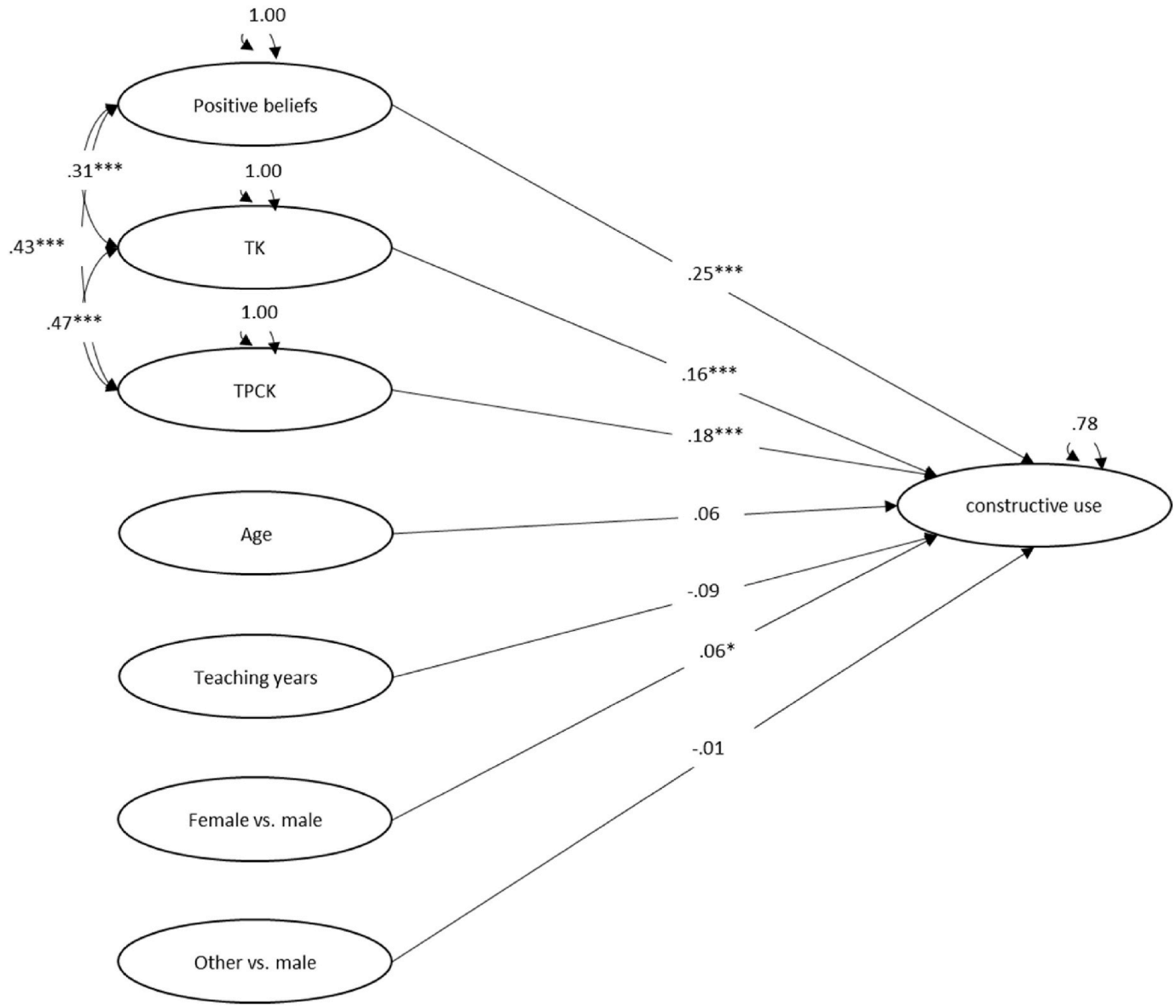

Fig. 10. Relationship between personal factors and constructive use.
Note. ***p < .001, **p < .01, *p < .05. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

vocational (both full-time and dual) and general education, in favour of the former.

Goal clarity is also the only school-related factor that consistently constitutes a significant and positive predictor of all three personal factors (positive beliefs, TK, and TPCK). In the case of positive beliefs and TPCK, the model also presented the same differences across school types, with both dual and full-time VET presenting significant differences with respect to general education and no significant differences between the two VET school types. In the case of positive beliefs, the differences were in favour of vocational education, while in the case of TPCK, the opposite pattern emerged. However, considering TK, no differences across school types emerged, but informal collaboration and leadership support also played a significant role, despite the latter being negatively related to teachers' technological knowledge.

Regarding teacher-related factors, teachers' positive beliefs about digital technologies and their TK and TPCK were consistently significant predictors of all four types of quality of technology use. Additionally, lower teaching experience turned out to be a significant predictor of more frequent passive and interactive activities. Age was only a significant predictor for passive learning activities, with a higher frequency for more aged teachers, and gender was only a significant predictor for constructive activities, with females integrating constructive activities more frequently than men.

Overall, these results align with previous studies, both in general and in vocational education, showing that personal, teacher-related factors seem to play a more important role in integrating technology than school-related ones (Cattaneo et al., 2022; Lucas et al., 2021), although school-related factors sometimes play an indirect role in technology integration, mediated by teachers' digital competences (Ninković et al., 2023; Petko et al., 2018).

However, looking closer, we also discern that some school-related factors (especially goal clarity for constructive activities and for all personal factors, and informal collaboration for interactive activities and TK) are becoming significant predictors of both the quality of technology integration and personal factors. This interesting distinction can be attributed to more advanced activities in pedagogical terms requiring not only specific technology-related skills (ability beliefs) and positive value beliefs towards technology but also a larger perspective and an all-round professional development, of which external factors such as collaboration with colleagues are also part (Sancar et al., 2021). Indeed, frameworks of teachers' digital competence explicitly include competence areas related to communication and collaboration with colleagues, other educators, and outside experts (e.g. the DigCompEdu, Redecker & Punie, 2017; the United Nations Educational, Scientific and Cultural Organization framework, UNESCO, 2011). They also include competences related to identifying and exploiting the interplay between school (and national) digitalisation policies and common classroom practices, allowing both the design and implementation of classroom practices compliant with these policies, and vice-versa to develop, share, and implement a school-level vision and an action plan about

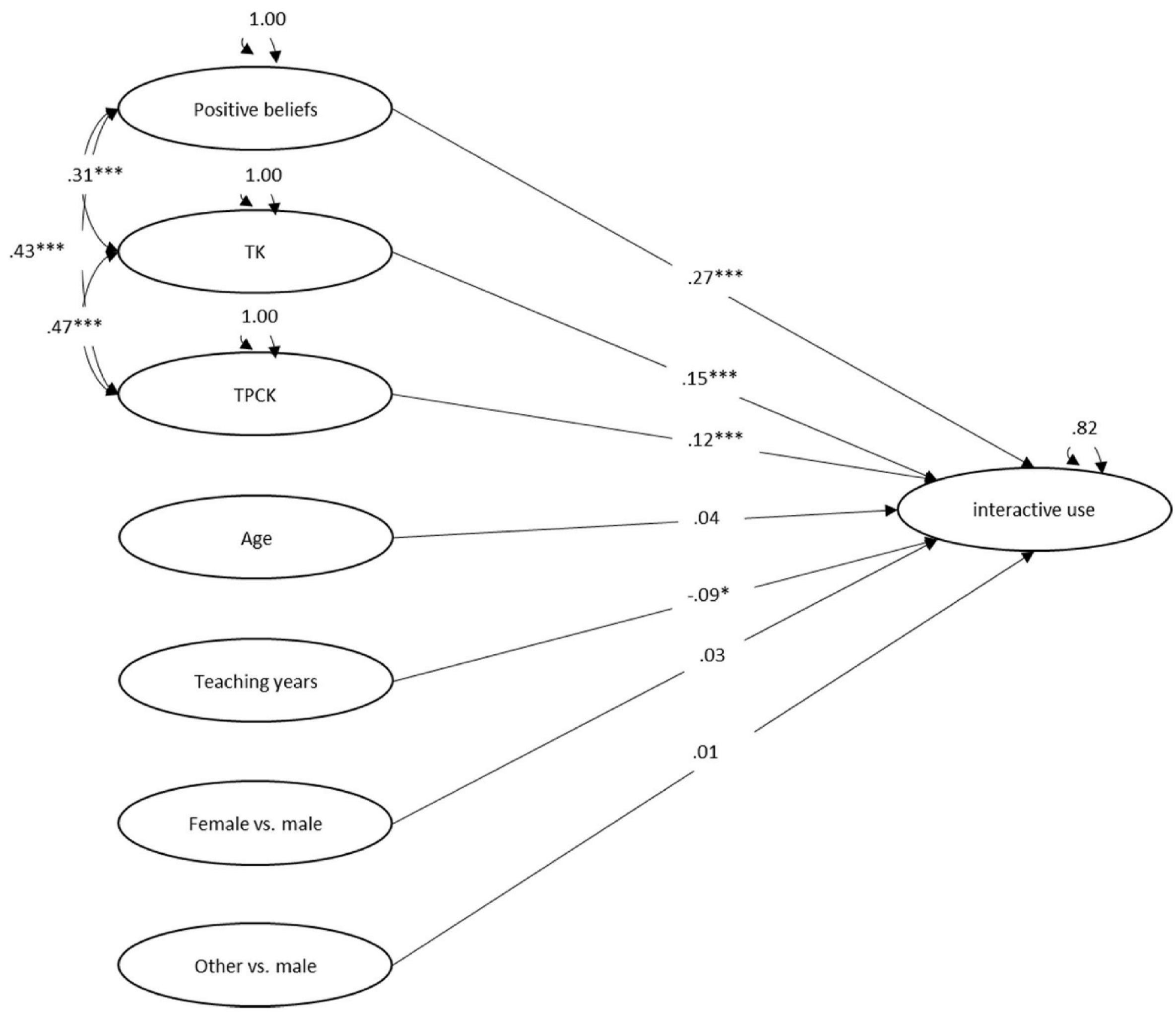

Fig. 11. Relationship between personal factors and interactive use.
Note. $***p < .001$, $**p < .01$, $*p < .05$. All standardized path coefficients and covariances between latent variables and variances explained by the endogenous variables are depicted. The measurement models are not presented.

technology integration (Fau & Moreau, 2018; UNESCO, 2011).

These outcomes become even more worthy of attention when considering further results on the differences between school types. Indeed, our assessment of the effects of school-related factors on technology integration revealed that teachers in both full-time and dual vocational schools reported much higher constructive and interactive use than teachers in general education schools. Passive activities were also significantly more common in dual vocational schools than in general education schools. An immediate interpretation would lead us to think that the different structures of the curricula in the two programmes could lead to these differences. However, considering that full-time VET schools have curriculum- and discipline-based structures that are similar to those of general education schools, these differences should be interpreted based on the specificities of vocational education, independent of the dual or full-time structure of the curriculum. These differences could be due to the different orientation of vocational education compared to general education, with the former being much more sensitive to the digital transformations of the world of work and more practice-oriented and the latter being more focused on preparing learners to access an academic path, thus more theory-oriented. This interpretation is also supported by the significant role played by goal clarity—another significant predictor of the three personal factors—which could reflect a relationship with economic needs and an orientation to the market, which is more common in VET schools than in general education.

Finally, a difference in the specific instructional strategies enacted in the two contexts could also be an influencing factor. Indeed, vocational teachers' training curricula were recently reorganised according to a specific pedagogical model based on the concept of professional or life situations (Boldrini et al., 2014; Ghisla et al., 2022). This model encourages teachers to approach theoretical issues by starting from concrete and tangible experiences. In principle, this could present more opportunities to integrate constructive and interactive activities at school, considering that homework is not as usual in vocational education as it is in general education. However, our data do not inform us of the correctness of these hypotheses, indicating the need for further and specific investigations.

4.1. Limitations

Despite its merits, this study presents some limitations that are worth considering. First, our results rely on self-reported data that could be subject to over- or under-estimation. The results of asking people about their competence can differ from those of asking them to perform a task for which the same competence is required. A similar issue concerns school-related factors, for which we also used teachers' subjective perceptions instead of objective measures of the school environment. Future research should consider integrating concrete tasks for an objective assessment of the digital competence level, objective data about school-level factors (e.g. the number of technological devices for

Table 4
Overview of the significant relationships between the factors investigated.

Relationship between school-related factors and technology integration				
Predictor	Type of learning activity			
	Passive	Active	Constructive	Interactive
Dual VET vs General	***[a]		**[a]	***[a]
Fulltime VET vs General		**[b]	**[b]	***[b]
Fulltime VET vs Dual VET		*[b]		
ICT importance in the school strategy		*		
Goal clarity			*	
Informal collaboration				*
Relationship between school-related factors and personal factors				
Predictor	Personal factor			
	Positive beliefs	TK	TPCK	
Dual VET vs General	*[a]		*[c]	
Fulltime VET vs General	**[b]		*[c]	
Goal clarity	***	*	*	
Informal collaboration		***		
Leader support (negative)		*		
Relationship between personal factors and technology integration				
Predictor	Type of learning activity			
	Passive	Active	Constructive	Interactive
Positive beliefs	***	***	***	***
TK	**	***	***	***
TPCK	***	***	***	***
Age	*			
Gender (Female is higher than male)			*	
Teaching years	*[d]			*[d]

Note. *$p < .05$; **$p < .01$; ***$p < .001$.
[a] Dual VET is higher.
[b] Fulltime VET is higher.
[c] General is higher.
[d] Negative: less experience, higher level.

teachers and students, the number of teachers' training opportunities, and the number of training hours attended), and objective scales measuring TPACK (Drummond & Sweeney, 2017; Fabian et al., 2024; von Kotzebue, 2023). The choice of which personal and school-related factors to include in the analysis can also be a matter of debate and improvement, given that the literature about beliefs does not only include ability and value beliefs but also pedagogical beliefs (Ertmer, 2005).

Second, our dataset could be prone to mono-source bias, as only teachers have been involved. Although other challenges arise, given that each student has multiple teachers, involving students in assessing the quality of teachers' technology integration could help go beyond this limitation. Third, the teachers participated on a voluntary basis, which could have resulted in self-selection bias. Fourth, in our analysis of the quality of technology integration through the ICAP model, we used teachers' responses to questions about the frequency of activities, which circled back to a quantitative frequency variable. Although recent studies have called back into question the predominant importance of quality over quantity regarding technology integration in education (OECD, 2023), there is a need for closer and sharp operationalisation of the quality aspect of technology integration.

Moreover, although considering the quality of technology integration through the ICAP model allows us to take a very preliminary step towards differentiating the teachers' decision-making process regarding technology integration—for example, by distinguishing teacher-versus student-centred activities and by differentiating these latter depending on the degree of students' cognitive engagement—further research is needed to shift attention from a product-oriented to a process-oriented quest (Kopcha et al., 2020; Lachner et al., 2024). Furthermore, as previously mentioned, despite our previous knowledge (Petko et al., 2018) that teacher-related factors mediate the relationship between school-related factors and technology integration, we did not have enough clusters (schools) and longitudinal data to perform multilevel mediation with several mediators or combine blockwise school-related and personal factors in structural equation modelling, indicating a prospective avenue for future studies. Finally, having used cross-sectional data, our analysis could not allow us to investigate the causal relationship between all the factors we considered, indicating the need for longitudinal studies in the future.

4.2. *Theoretical and practical implications*

4.2.1. *Theoretical implications*

The present study makes two contributions to the existing literature. On the one hand, the findings elucidate how personal and school-related factors pertaining to technology integration vary in terms of their significance, depending on the quality of technology-supported learning activities. On the other hand, the study provides evidence regarding the existence of differences between the two co-existing education systems in upper secondary education, namely general and vocational education. In terms of the former element, the findings confirm the importance of personal factors for technology integration when assessing its quality. Positive beliefs, TK, and TPCK consistently emerged as significant predictors, irrespective of the quality of technology integration. With school-related factors, the same is true only with regard to goal clarity for constructive activities and informal collaboration for interactive activities. Nevertheless, it is necessary to emphasise that this represents merely the initial stage of an investigation that should focus on quality in preference to quantity and that should more deeply consider the process rather than the outcome of technology integration (Kopcha et al., 2020). Further research is needed to gain a deeper understanding of the implications and requirements of these four distinct types of qualitatively different learning activities for teachers and students.

Apart from providing empirical evidence previously missing in the literature, our evidence of the differences between general and vocational education offers a compelling rationale for the assertion that technology integration is not only a matter of curriculum structure, suggesting the involvement of additional, hitherto unidentified, factors within the system itself. It therefore becomes imperative to also direct research efforts towards the elucidation of these factors.

4.2.2. *Practical implications*

This study also has some practical implications for teacher education and professional development. We opened this paper by highlighting the current challenge of training teachers in technology integration. The constant development of new technological possibilities makes this challenge even more difficult. However, this study offers some insights into important aspects to focus on in teacher education.

A first confirmation concerns how important it is to combine both a technological-oriented and a pedagogically strong perspective. Both TK and TPCK are confirmed to be fundamental components of technology integration, independent of the kind of activity proposed to students. Second, our results invite us to work more on specific school-related factors, which, although proved to be considerably important in previous studies, emerged as less determinant in our dataset, especially when considering general education. This motivates us to suggest that school leaders, especially in general education, should aim for goal clarity to foster the development of teachers' appropriate value and ability beliefs regarding technology integration. Informal collaboration also emerged as an important school-level factor, and promoting it more in teacher education and school management could be a starting point towards strengthening the school-related factors that seem to play a not-so-important role in our dataset.

Finally, considering the differences that emerged from the two systems makes us think that the orientation towards the world of work and practice, characterising vocational education in particular, could also be promoted more in general education. This mirrors also in teacher education, where vocational teachers are proposed pedagogical models constantly referring to professional situations and experiences (Boldrini et al., 2014; Ghisla et al., 2022) and where context-specific instructional models are also available when dealing, in particular, with technology integration (e.g. Schwendimann et al., 2015). This approach could also be promoted more in general education.

4.3. Conclusion

This study analysed data from a survey of 1660 teachers at upper secondary level schools in Switzerland using SEM with cluster-robust standard errors to better understand the extent to which personal and school-related factors affect the quality of technology integration in teaching at the secondary II level and particularly how this differs across school types, contrasting general and vocational education. We considered technology integration from a qualitative perspective, examining the extent to which teachers offered qualitatively different teaching and learning activities to learners. We differentiated the learning activities based on the ICAP framework—that is, based on different levels of learners' cognitive engagement.

The study narrows the gap in the research on upper secondary schools, which remains scant, and on possible differences across curriculum types by contrasting general and vocational education. Regarding the former, apart from the confirmation that technologies are used very frequently in upper secondary level schools in Switzerland, we further confirmed the importance of considering personal factors in training teachers to integrate technologies in their activities. As per the school-related factors, goal clarity was revealed to be an important predictor of personal factors, contributing to further discriminating the differences between school types. Our comparison of curriculum types revealed that vocational schools seem to be a bit more advanced in their technology integration, which could be due to the pressure they face from the labour market and the general digitalisation of their domain. Indeed, including the comparison of full-time VET curricula, which are structurally similar to general education curricula, allowed us to hypothesise that the differences between general and vocational education are not attributable to the structure and organisation of the curriculum but more likely to the culture of the vocational system itself. Especially in this latter comparison between school types, the study paves the way for further investigations of the differences between school systems that could be useful in informing teacher education and technology-enhanced learning in general.

CRediT authorship contribution statement

Alberto Cattaneo: Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Formal analysis, Conceptualization. **Maria-Luisa Schmitz:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Philipp Gonon:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Conceptualization. **Chiara Antonietti:** Writing – review & editing, Investigation, Data curation. **Tessa Consoli:** Writing – review & editing, Investigation, Data curation. **Dominik Petko:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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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.2024.108475.

Data availability

Data are planned to be available in a public repository at the end of the project, in December 2024.

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