

ORIGINAL ARTICLE

Profiling Gaps in STEM Teachers' Digital Technology Use Related to Their Self-Perceived Capability

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ABSTRACT

This study examined STEM teachers' self-perceived digital competence and the digital technologies that they reported as missing from classroom practice. Drawing on the DigCompEdu framework and a person-Centered approach, latent class analysis (LCA) was applied to questionnaire responses from 810 pre-service and in-service STEM teachers from eight European countries. Teachers' self-assessed digital competence was measured using nine Likert-scale items, and open-ended responses concerning missing technologies were analyzed using inductive content analysis. The LCA identified four profiles, labeled Emerging, Integrative, Established, and Pioneer, which differed in their self-reported competence, perceived knowledge, and training related to digital technology use. The qualitative analysis yielded five umbrella categories of missing technologies: Emerging, Immersive and Intelligent Technologies; Subject Specific, Experimental and Constructive Technologies; Digital Learning Environments, Content and Interaction; Digital Infrastructure and Core Classroom Technology; and Assessment, Support, and Collaboration. Across the sample, the most frequently reported missing technologies were related to emerging and intelligent technologies, followed by subject-specific and interactive learning technologies. Comparison across the profiles indicated that higher-competence groups reported more differentiated and specific technology gaps, whereas lower-competence groups more often provided empty, vague, or no-gap responses. The findings suggested that higher self-perceived digital competence was associated not necessarily with fewer barriers, but with a clearer awareness of unmet technological needs. The study highlighted the value of combining person-centered quantitative analysis with qualitative categorization to better understand variation in teachers' digital competence profiles and their perceived classroom technology needs.

KEY WORDS: Latent Profile Analysis; Educational Technology; Teacher education; Digital competence

INTRODUCTION

The rapid pace of digital transformation has substantially reshaped educational practice, with STEM education being particularly well positioned to benefit because of its close relationship to technological application (Castro et al., 2021; Guandalini, 2022). Contemporary digital tools, ranging from interactive simulations such as PhET to immersive virtual environments, provide students with opportunities to visualize abstract concepts, conduct experiments, and engage in inquiry-based learning beyond the constraints of the traditional classroom (Althubyani, 2024; Laius and Orgusaar, 2025; Walan, 2020). This reliance on digital technologies is further intensified by the COVID-19 pandemic, which accelerated the integration of digital media into everyday teaching practices worldwide (Besser et al., 2022; Howard et al., 2021).

Reflecting these developments, international frameworks such as the *Next Generation Science Standards* (NGSS Lead States, 2013) and the *European Framework for the Digital*

Competence of Educators (DigCompEdu; Redecker, 2017) have reinforced expectations for the meaningful integration of technology into teaching (Althubyani, 2024). Similarly, national reforms in countries such as Norway and Estonia increasingly position the use of digital tools as a foundational competence comparable to literacy and numeracy (Instefjord and Munthe, 2016; Laius and Orgusaar, 2025). Consequently, teachers are expected to develop digital competence that extends beyond basic technical proficiency and enables them to support students in critically evaluating, creating, and communicating scientific information in a digitally mediated society (Althubyani, 2024; Laius and Orgusaar, 2025; Lin et al., 2023).

The European Framework for the Digital Competence of Educators (DigCompEdu), developed by the European Commission's Joint Research Centre, provides a widely recognized framework for conceptualizing and assessing educators' digital competence (Redecker, 2017). As digital

technologies become increasingly embedded in teaching and learning, DigCompEdu offers a shared language for describing the knowledge, skills, and practices required for effective pedagogical use of these technologies across educational contexts. Its broad applicability has also contributed to its growing use in educational research and teacher professional development (Cid-Martínez et al., 2025; Santos et al., 2025).

DigCompEdu identifies 22 competences organized into six domains: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence (Redecker, 2017). In addition, the framework includes a six-level progression model ranging from Newcomer (A1) to Pioneer (C2), which supports the interpretation of educators' developmental stages in relation to digital competence. In the context of the present study, DigCompEdu serves as the conceptual foundation for understanding teacher digital competence and for framing some of the dimensions through which teachers' self-perceived competence in using digital technologies is examined.

Against this background, it is important to examine the gap between policy-level expectations for digital competence and the realities of classroom practice. Although curricular reforms and professional frameworks increasingly emphasize the meaningful integration of digital technologies, these expectations may not be uniformly reflected in teachers' everyday teaching and educational digital ecosystems organization for economic co-operation and development (OECD, 2023). Understanding this discrepancy requires attention not only to the technologies that teachers currently use but also to those they perceive as missing from their practice, so called "missing technologies." These technologies may remain absent due to the teacher for example lacking access to, have access to, but choose not to use, feel unable to use due to insufficient competence or the technology might be unavailable in their institutional context. Such absent technologies may reveal important constraints related to perceived competence, pedagogical readiness, or contextual conditions. Although science education provides a central context for considering these issues, the present study is not limited to science teachers and science education alone. Rather, the empirical analysis examines pre-service and in-service STEM teachers across multiple subject domains. At the same time, teachers need not be treated as a homogeneous group, as their experiences, confidence, competence, and patterns of technology use are likely to differ in meaningful ways. For this reason, a person-centered approach is warranted and more emphasis placed upon how digital technology adoption might differ across competence levels and what technologies are missing from classroom use.

The present study addresses these issues by adopting a person-centered perspective on STEM teachers' self-assessed digital competence and their perceptions of technologies that remain absent from classroom practice. Specifically, the study is

guided by the following research questions:

- RQ1. What latent profiles of pre-service and in-service STEM teachers can be identified based on their self-assessed skills and knowledge related to digital technologies?
- RQ2. Which digital technologies do STEM teachers report as still missing from classroom use?
- RQ3. How do the characteristics of the technologies reported as still missing vary across the identified teacher profiles?

THEORETICAL FRAMEWORK

Defining Digital Technologies in STEM Education

Digital technologies in STEM education encompass a broad range of tools and platforms that support teaching, learning, and assessment. Some of the key categories of these technologies and their applications are presented below. Because the STEM disciplines differ in their content, methods, and instructional traditions, digital technologies serve varied pedagogical purposes across subjects and educational levels. This section outlines several categories of digital technologies that are relevant to STEM education more broadly, rather than to any single discipline.

One category consists of subject-specific, experimental, and constructive technologies tools that support empirical inquiry and data-based learning, such as physical data loggers, smartphones, and digital video recorders, which enable students to collect authentic experimental data in local settings. This data can subsequently be modeled and visualized through web-based tools that scaffold the learning process, thereby supporting hypothesis generation and testing in a manner analogous to remote or virtual laboratories (Wong et al., 2019). Virtual laboratories and simulations similarly provide environments, in which students can engage in scientific inquiry without physical constraints, often enhanced by scaffolded online tools (Levin and Tsybulsky, 2017). Digital programming technologies, such as Kitsi Blocks or Micro: bits, further extend this category by connecting physical and virtual environments and enabling thematic, transdisciplinary learning experiences that encompass science, mathematics, digital technology, and the arts, for example, within Science, Technology, Engineering, Arts, and Mathematics projects (Wellington et al., 2020). Although these tools have often been discussed in the context of science education, their pedagogical logic extends to other STEM subjects that involve investigation, modeling, and interpretation of data.

A second category comprises digital learning environments, content, and interaction tools, that is, general-purpose platforms supporting the organization of teaching and communication across STEM subjects. Learning management systems (LMS), such as Canvas and Moodle, facilitate the delivery of content and the structuring of learning activities, allowing teachers to organize instruction coherently across topics and educational levels (Kamath et al., 2025).

Closely related is a third category of assessment, support, and

collaboration tools, which extend the functionality of digital learning environments toward the monitoring and guidance of student learning. LMS-integrated features such as auto-graded tasks, immediate feedback, and the organization of assessment data support both formative and summative assessment strategies, enabling teachers to monitor student understanding and guide instructional decision-making, thereby contributing to assessment-for-learning practices in a wide range of STEM subjects and educational contexts (Miedijensky and Haran, 2026).

A fourth category, emerging, immersive, and intelligent technologies, constitutes a rapidly expanding set of digital tools in STEM education. What technologies are considered emerging are subject to change over time (Chng et al., 2023), but during this timeframe it's used to describe technologies such as artificial intelligence (AI), augmented reality (AR), and virtual reality (VR) or other such technologies being adopted to education in the 2020's. This category has seen a marked increase in research and classroom implementation since 2017, particularly within the science subjects and to a lesser extent within mathematics, technology, and engineering (Ebrahimi et al., 2023; Chng et al., 2023). This category includes smartphone- and tablet-based AR, which remains the most widely used platform due to its accessibility and low cost, as well as immersive VR headsets, which have seen increasing classroom use in recent years (Ebrahimi et al., 2023). These technologies have been reported to support students' academic achievement, engagement, and motivation by rendering abstract or spatially complex concepts into manipulable three-dimensional representations, and by enabling authentic, safe, and cost-effective inquiry in environments that may otherwise be inaccessible in a K–12 setting (Ebrahimi et al., 2023; Jiang et al., 2025). When combined with AI related solutions, these technologies further enable programmatically generated learning environments, real-time adaptive feedback, and intelligent tutoring tailored to individual student progress (Chng et al., 2023; Lampropoulos, 2023).

Finally, all of the above categories rely on a foundation of digital infrastructure and core classroom technology, including networked devices, projectors, interactive displays, and stable connectivity. Although these technologies are seldom the focus of pedagogical discussion, they constitute a necessary condition for the adoption and integration of the other categories described here.

For the purposes of the present study, digital technologies in STEM education can be understood as including both foundational and advanced tools that support inquiry, experimentation, content delivery, interaction, assessment, and collaboration (Levin and Tsybulsky, 2017; Miedijensky and Haran, 2026; Wellington et al., 2020; Wong et al., 2019). This broad conceptualization is particularly important when examining which technologies teachers perceive as absent from their classroom practice. At the same time, the expanding range of available tools means that not all technologies are equally accessible, visible, or pedagogically integrated in classroom

practice. Understanding digital technology use in STEM education, therefore, requires attention not only to the tools teachers currently employ but also to the barriers that shape access, adoption, and awareness of technologies that remain absent from practice.

Access and Barriers to Digital Technology Use

Although access to digital tools in education has increased over time, the integration of technology into classroom practice remains shaped by a complex interplay of structural and personal factors. These barriers are often categorized as first-order and second-order barriers (Ertmer, 1999; Ertmer et al., 2012). First-order barriers refer to obstacles outside teachers' immediate control, such as limited time, insufficient training, lack of technical support, financial constraints, and unequal access to infrastructure. Second-order barriers, in contrast, relate to teachers' beliefs, confidence, and willingness to change established pedagogical practices.

Time is consistently identified as one of the most persistent barriers, as teachers often lack the opportunity to explore, test, and prepare high-quality technology-supported learning experiences (Francom, 2020; Hew and Brush, 2007; Kopcha, 2012). Similarly, inadequate training and limited technical support may leave teachers familiar with the basic operation of digital tools without enabling them to use these tools in pedagogically meaningful ways (Inan and Lowther, 2010; Mouza, 2011). Emerging technologies such as AR and VR may also remain underused because of high equipment costs, maintenance demands, and bandwidth requirements (Albishri and Blackmore, 2025). In addition, persistent inequities in students' home access to devices and stable internet connections may discourage teachers from adopting technology-dependent practices that deepen existing inequalities (Kormos and Wisdom, 2023).

Beyond these structural constraints, internal factors also play an important role. Teachers' beliefs about the pedagogical value of technology, as well as their confidence in using and troubleshooting digital tools, strongly influence whether technologies are meaningfully integrated into teaching (Ertmer et al., 2012; Hixon and Buckenmeyer, 2009). Successful integration may also require shifts away from teacher-centered practices toward more student-centered and inquiry-oriented forms of instruction (Fabry and Higgs, 1997). As a result, the absence of certain technologies from classroom practice cannot be explained solely by lack of access; it may also reflect differences in teachers' perceptions, confidence, and pedagogical orientations. This makes it necessary to consider more closely how teachers evaluate digital technologies and what shapes their willingness to adopt them. In the present study, this literature on first- and second-order barriers is used as a complementary interpretative perspective rather than as a directly measured framework.

Technology Acceptance and Adoption of Digital Technologies

The technology acceptance model (TAM) is a widely adopted framework in educational research for explaining why some

digital technologies are integrated into teaching practice while others remain underused (Granić and Marangunić, 2019). The model proposes that technology adoption is shaped primarily by two distinct beliefs: Perceived usefulness, defined as the extent to which a technology is seen as enhancing job performance, and perceived ease of use, defined as the extent to which using the technology is perceived as requiring little effort (Davis, 1989). Together, these beliefs influence users' willingness to adopt and sustain the use of a technology (Davis et al., 1989).

Although the concepts of perceived ease of use and teachers' self-perceived competence are not equivalent, in the present study, the constructs are used as they are conceptually related. Educators who regard themselves as more capable of using digital technologies may also be more likely to perceive them as manageable and accessible (Venkatesh, 2000; Venkatesh and Bala, 2008). Conversely, technologies that are perceived as complex or demanding may be less likely to be adopted in classroom practice. As the questionnaire is only inspired by TAM, but does not outright measure any of the TAM constructs, it is used as a cautious interpretive perspective for reflecting on possible connections between self-perceived digital competence and technology adoption.

However, while TAM establishes robust relationships between the factors that influence behavioral intention and actual technology use, the model does not fully address the underlying reasons why an educator might seek to adopt a particular technology for classroom use. Perceived usefulness, as defined within TAM, captures the belief that a technology enhances job performance, but it does not specify what makes a technology valuable in pedagogical terms and may not fully explain whether a technology is adopted or remains absent from classroom practice.

Integrating Technologies in a Pedagogically Meaningful Way

Technological pedagogical content knowledge (TPACK) is a theoretical framework developed to describe the complex and specialized knowledge required by teachers for effective technology integration in classroom practice (Alrwaished et al., 2017; Jimoyiannis, 2010; Koehler et al., 2013). Formally introduced by Mishra and Koehler (2006), the framework expands on Shulman's (1986) concept of Pedagogical Content Knowledge (PCK) by identifying Technological Knowledge (TK) as a critical third body of knowledge alongside Content Knowledge (CK) and Pedagogical Knowledge (PK). The framework posits that effective teaching with technology depends on a flexible and integrated understanding of these three core components and the four knowledge domains that emerge from their intersections: PCK, Technological CK, Technological PK, and the central construct of TPACK (Mishra and Koehler, 2006).

Unlike approaches that treat technology as a supplemental addition to existing practice, TPACK emphasizes a dynamic transactional relationship between content, pedagogy, and technology (Archambault and Barnett, 2010; Jimoyiannis,

2010). A change in any one of these domains necessitates corresponding adjustments in the other two, leading to new ways of representing and engaging with subject matter (Mishra and Koehler, 2006). Expert teaching with technology therefore requires educators to navigate what Koehler et al. (2013) describe as the essential tension between these domains to identify optimal solutions for specific learning situations. Furthermore, the framework situates this interplay within the broader educational context, acknowledging that technology integration is influenced by factors such as school culture, resource availability, and the particular needs of a given learning environment (Koehler et al., 2013; Mishra and Koehler, 2006).

The integrative nature of TPACK also has important implications for understanding teachers' awareness of available digital technologies and their ability to identify technologies that are absent from their practice. TK, as conceptualized within TPACK, encompasses not only the ability to operate specific tools but also a broader awareness of which technologies exist and how they may serve pedagogical purposes within a given content area (Koehler et al., 2013; Mishra and Koehler, 2006). Teachers with stronger integration of technological, pedagogical, and CK may therefore be better positioned to recognize gaps in their current technology use and to articulate which tools can meaningfully enhance their teaching but are not yet available or adopted. Conversely, teachers with more limited TK may lack the awareness needed to identify such gaps, potentially resulting in a narrower perception of what is missing from their practice.

Taken together, the frameworks reviewed above complement each other in the present study. Teachers' self-perceived digital competence, as reflected in the questionnaire items, is understood primarily with reference to the European Framework for the Digital Competence of Educators (DigCompEdu), which provides the main conceptual background for the instrument. TPACK and the literature on first- and second-order barriers offer complementary interpretive perspectives on the pedagogical and contextual conditions of technology integration, while TAM is used as a cautious lens in the discussion of the findings. Accordingly, the latent classes identified in this study are interpreted as descriptive response profiles of teachers' self-perceived digital competence rather than as predefined categories derived from any single framework or as fixed teacher types.

METHODOLOGY

Teacher Self-Assessment as a Research Approach

In this study, teachers' digital competence is assessed using a Likert-scale questionnaire based on the DigCompEdu Framework. Self-assessment instruments are widely used in educational research to capture teachers' perceived competence, particularly when examining complex and multidimensional constructs such as digital competence. Compared with objective performance-based assessments,

self-report questionnaires enable efficient data collection across multiple domains with lower resource demands (Kastorff et al., 2022; Schmid et al., 2020). However, self-report measures capture perceived rather than objectively demonstrated competence, and responses may therefore be influenced by overestimation or underestimation bias (Kunter and Klusmann, 2010; Schraw, 2009). The findings need to be interpreted with this limitation in mind.

Participants and Setting

Participants were recruited using a non-probability sampling strategy that combined convenience sampling with elements of snowball recruitment. The online questionnaire, consisting of multiple-choice and short-answer items, was distributed by consortium members across multiple institutions in the eight participating countries. In some cases, recipients were also invited to forward the survey to other potential participants within their professional networks. Accordingly, the sample was recruited through institutional and professional network channels rather than through random selection and should be regarded as a regional sample from each participating country.

The final sample comprised 810 European pre-service and in-service STEM teachers from eight countries. Subgroups were from Estonia ($n = 68$), Finland ($n = 69$), Germany ($n = 111$), Latvia ($n = 81$), Croatia ($n = 208$), Hungary ($n = 88$), Portugal ($n = 80$), and Turkey ($n = 104$). Of the 810 pre-service and in-service teachers, 29 reported no teaching experience, 261 reported <5 years of teaching experience, 83 reported over 5, but <10 years, 82 reported over 10 but <15 years, and 351 reported more than 15 years of teaching experience. Four respondents did not report their teaching experience.

Given the voluntary nature of participation and the use of network-based recruitment, the sample is likely to be affected by self-selection bias. In addition, the uneven distribution of participants across countries means that the aggregated findings may be disproportionately shaped by the larger national subgroups. Consequently, although the sample includes respondents from different regions of the European Union, variation within countries may not be fully captured. The findings need to be interpreted with caution, as broader generalization require additional data. Nevertheless, despite these limitations, the sample provides useful insight into responding STEM teachers' self-evaluated competence to use digital technology.

Questionnaire Items

The items were presented as part of a larger survey into teacher self-evaluated capabilities in various STEM and pedagogical practice related topics. This survey was developed by a project consortium consisting of researchers from seven universities located in different European countries. The questionnaire items presented in this paper were developed by a team of experts in educational technology research. These constructs were then discussed with the group of international researchers and further refined to a piloting stage. The items were piloted with a total of 170 STEM teachers and STEM

teacher students with participants from each participating country. During the piloting feedback was collected from the participants and modifications were made to the questionnaire items. Furthermore, during this stage, two of the items were cut from the final questionnaire, as they were evaluated to be too overlapping with other items. After the piloting phase, the finalized instrument was translated from English to the local languages by a group of STEM education researchers from each project partner to ensure nuance in each item was not lost in translation. Each item represented a construct that was directly measured and their intention was to measure some of the teacher proficiencies that might affect the DigCompEdu competence areas. As the DigCompEdu questionnaire existed and undergone a rigorous testing, it was deemed worthwhile to further research how teachers perceived their own capabilities directly related to technology integration and pedagogical use and what technologies the currently in-service and pre-service teacher's might identify as missing from their classroom use, as this could potentially be used in the curriculum and course developments at the university level.

Answers were collected using a 6-point Likert-scale, where for statements 1, 2, 7, 8, and 9 options ranged from Pr(1) "do not agree at all" to Pr(6) "very much agree" and for items 3–6 options ranged from "not confident" to "very confident." The statements were as presented in Table 1.

In addition to these nine Likert-statements, one open-ended question was presented to the respondents, which was:

What technologies, tools, and applications should additionally be in use in your teaching, but for some reason were not currently being utilized?

Because the open-ended question did not ask participants to specify why a given technology was absent, the responses did not directly distinguish between lack of access, non-use,

Table 1: Statements used in the questionnaire and their corresponding codes

Code	Description
How strongly do you agree with each of the following statements:	
D1	I am aware of suitable digital technologies for promoting education
D2	I feel there is a need to utilize the possibilities of digital technologies in education
How confident do you feel you are to:	
D3	assess the suitable use of digital technologies
D4	ensure the usefulness of digital technologies
D5	guide the using of digital technologies
D6	adapt to new ways of using digital technologies
How strongly do you agree with each of the following statements:	
D7	I prefer to use digital technologies as much as I like, because I do not have major difficulties in this area.
D8	When I try to use digital technologies, the difficulties I encounter do not make me give up on using them.
D9	I have received sufficient training to use digital technologies to the extent I like

insufficient competence, insufficient support, and unmet pedagogical needs. Interpretations concerning underlying reasons for absence were therefore treated as tentative.

Person-Centered Approaches to Teacher Profiling

Latent class analysis (LCA) was employed as a person-centered analytical approach to identify unobserved subgroups of teachers based on their response patterns. In educational research, LCA was widely used to capture heterogeneity within teacher and student populations by identifying distinct profiles that might differ in beliefs, practices, or professional needs, rather than focusing solely on average relationships between variables (Collins and Lanza, 2010; Lamont et al., 2018; Oliveira and Lopes, 2025). In the present study, latent class models comprising one to 10 classes were compared using multiple information criteria. The four-class solution was selected as the primary model because it yielded the lowest Bayesian Information Criterion (BIC) and Consistent Akaike Information Criterion (CAIC) values, indicating the best balance between model fit and parsimony. Although the Akaike Information Criterion (AIC) and sample-adjusted BIC suggested greater model complexity, the four-class solution was preferred on both statistical and substantive grounds. This decision was further supported by Nylund et al. (2007), who identified BIC as a particularly accurate criterion for determining the correct number of classes. In the present analysis, the lower BIC value for the four-class model compared with the five-class model suggested that four classes were sufficient to capture respondents' self-reported competence across the questionnaire items.

Qualitative Content Analysis

The open-ended survey responses were analyzed using inductive content analysis in accordance with Elo and Kyngäs (2008). The analysis was data-driven and conducted by one researcher in ATLAS.ti. 26. During the initial phase, *in vivo* coding was used to capture respondents' own wording, particularly in cases where they explicitly named a technology, tool, or application perceived as absent from their classroom practice. As each code was recorded in ATLAS.ti, a codebook was developed and maintained throughout the analysis to document coding decisions and support consistency.

Following the initial coding phase, the responses were compared and grouped according to their pedagogical use, leading to the development of higher-order categories. This process was iterative and continued until a manageable set of umbrella categories was established to encompass the full range of individual codes. In the final categorization, each technology, tool, or application was assigned to one umbrella category only (Appendix A). Codebook was developed by first coding every technology *in vivo* and then generalizing pieces of technology such as moving from Moodle and Canvas to LMS and finally to Digital Learning Environments, Content, and Interaction. Where possible, pieces of technology that could be assigned to multiple categories were evaluated based on the principal characteristics of that tool, for example, code "AI for

support" was assigned to Emerging, Immersive, and Intelligent Technologies, since the AI part differentiates it from any other form of support and might carry a tacit meaning of automation.

Empty responses and responses explicitly stating no missing technologies were retained as a separate category, and unclear, uncertain, and ambiguous responses were grouped together. The answers classified in no missing technology were directly stating that they were either content with what they had now or that they did not need anything more. The unclear or vague category in turn was formed specifically for answers that were not empty, but, at the same time, did not provide a direct answer to the question at hand. For example, these answers would talk about barriers for adoption or justification for not using technology or stating, "I don't know," "nothing comes to mind," or "many missing," instead of mentioning any technologies by name. Although these responses did not always permit substantive categorization, they were retained because they might still provide meaningful information when examined in relation to the LCA profiles assigned to the teachers. The resulting categories were as presented and described in Subsection 4.2.

To enhance the trustworthiness of the analysis, the coding process followed a transparent and systematic procedure grounded in the principles of inductive content analysis. In addition, the final umbrella categories were discussed with other members of the research team to assess their interpretive adequacy and to support the credibility of the categorization.

RESULTS

LCA

Latent class models with one to 10 classes were compared using multiple information criteria. The analysis was done using Jamovi version 2.7.38 software and the snowLatent 2.7.5 package. The model comparison values were as presented in Table 2. The BIC and CAIC reached their minimum values for the fourclass solution, indicating the optimal balance between model fit and parsimony. Marginal prevalences of each class were presented in Table 3 for the 4 and 5 class solutions.

Based on the study by Nylund et al. (2007), BIC was shown to be an accurate method for identifying the number of classes correctly. Our statistics showed that the 4-class model produced a BIC score 114 lower than the 5-class model, while the 6-class solution offered an even worse BIC score, implying that the 4 classes were sufficient in describing the self-reported competences of the respondents to the questionnaire items. While the 5-class model seemed to classify respondents more cleanly than the 4-class model based on entropy (0.915 compared to 0.908) looking at the class sizes from Table 3, it is noted that the first class was relatively small, containing only about 4.4% of the participants, which suggested that this small class might not be necessary. Although AIC suggested additional model complexity, the fourclass solution was selected as the primary model due to its statistical support and substantive interpretability.

Table 2: Model comparison through multiple information criteria

Class	Log-likelihood	AIC	CAIC	BIC	Entropy	Df	G ²	AvePP
2	-9737	19693	20314	20205	0.924	700	9233	0.979
3	-9220	18768	19702	19538	0.904	645	8198	0.957
4	-8941	18320	19568	19349	0.908	590	7641	0.946
5	-8814	18176	19737	19463	0.915	535	7386	0.945
6	-8717	18092	19967	19638	0.896	480	7193	0.926
7	-8656	18079	20267	19883	0.904	425	7070	0.926
8	-8592	18061	20562	20123	0.886	370	6942	0.911
9	-8549	18086	20901	20407	0.900	315	6857	0.919
10	-8504	18106	21233	20684	0.878	260	6766	0.890

AIC: Akaike information criterion, CAIC: Consistent Akaike information criterion, BIC: Bayesian information criterion. Bolded values indicate the best-performing value of each criterion for class solutions.

Table 3: Marginal prevalences of each class for 4 and 5 class solutions. Here, classes are ordered from lowest self-perceived competence (class 1) to highest (class 5)

Classes	Probability	
Class 1	0.155	0.0438
Class 2	0.367	0.1362
Class 3	0.313	0.3506
Class 4	0.165	0.3051
Class 5	-	0.1642

With the 4-class solution, each respondent was placed in a category that best fit their response profile. Overall, 126 teachers were in class 1, 298 were in class 2, 253 were in class 3, and 133 were in class 4. Class 1 represents a sub-group of teachers, who felt the most negative towards their knowledge and training of digital technologies and their ability to direct the classroom use of digital technologies. This group was named as the “Emerging” group. Class 2 indicated a sub-group of teachers who recognized the benefit of digital technology use, but who reported lower agreement with the training-related item. This group was named the “Integrative” group. Class 3 indicated teachers, who overall feel that there was a need to use digital technologies in the classroom, and who are quite confident on their ability to use digital technologies in the classroom. Class 3 was named the “Established” group. Finally, the class 4 were the most confident in their ability to direct the use of digital technologies in the classroom and were named the “Pioneer” group. Class labels were created by looking at the profiles and inspired by the DigCompEdu labels. It should be noted that although the labels were similar to those used in DigCompEdu, it did not mean that a person answering to both questionnaires would be sorted to classes with the same name. In this case, labels were used simply to make referring to each class easier for the reader.

Since the background information contained the participant's country of residence, at relative prevalences of each class in the participating countries can be considered after the LCA was conducted for the whole population, each country's sample could be further analyzed and general level conclusions about

the differences between countries compared. This data was as presented in Table 4.

Based on the data Estonian, Finnish and German participants were least likely to belong to the Pioneer class with prevalence ranging from 5.88% to 8.70%. Latvian, Croatian, and Hungarian participants were equally likely to belong to the Pioneer class, with prevalences being 18.52%, 18.75%, and 18.89%, respectively. Portuguese and Turkish participants were most likely to report high self-perceived ability, and the Pioneer group was most prevalent in these countries (25.93% and 23.08%, respectively). Croatian participants were most likely to report low self-perceived ability (20.67%), followed by the Estonian participants (19.12%) and the Finnish participants (17.39%).

Missing Technologies from Classroom Use

Teachers' responses regarding missing digital technologies were grouped into five umbrella categories based on the primary pedagogical function of the technologies. Table 5 summarized the categories, their definitions, and total frequencies. A complete list of individual codes included in each category were provided in Appendix A.

Individual responses were first coded at a granular level and subsequently aggregated into umbrella categories reflecting their dominant pedagogical role. The umbrella categories and individual codes assigned to them were discussed with another researcher to strengthen the validity of the assignments. This approach prioritized analytical clarity while preserving traceability from individual codes to higherlevel categories (Appendix A).

The Emerging, Immersive, and Intelligent Technologies category was the most prevalent overall and was dominated by AI-related technologies, with AR and VR also strongly represented.

The Subject Specific, Experimental, and Constructive Technologies category was closely linked to discipline-specific practices, particularly in STEM education. Frequently reported items included laboratory tools, simulations, and data collection technologies, as well as robotics, maker tools, and games.

The Digital Learning Environments, Content, and Interaction category comprised reports of missing digital learning environments, interactive materials, media tools, and apps, along with modeling and writing tools.

The Digital Infrastructure and Core Classroom Technology category included reports of gaps in hardware, connectivity, and presentation technologies.

The Assessment, Support, and Collaboration category had the lowest overall prevalence. Reported items included tools for quizzes, assessment, learner support, and collaboration, encompassing both learner-directed and teacher-directed support tools.

Missing Technologies across Latent Profiles

The distribution of missing technologies varied across the four latent classes, as shown in Table 6. A total of 136 codes came

from the Emerging group, 329 came from the Integrative group, 265 came from the Established group and 150 codes came from the Pioneer group. The comparisons reported here were purely descriptive, as no inferential statistical tests were conducted.

Empty or absent responses constituted the most prevalent category across all four groups and were of comparable magnitude (Emerging: 29.37%; Integrative: 31.21%; Established: 28.06%; and Pioneer: 29.32%). Beyond this shared baseline, the distribution of reported gaps varied across the latent classes, while still retaining some overlap between neighboring classes. Because participants were assigned to their most likely latent class, some classification uncertainty was inherent in these comparisons.

For the Emerging group, the second most frequently mentioned category was uncertain or vague about missing tech (23.02%),

Table 4: Class prevalence in each participating country

Class	EST (%)	FIN (%)	DEU (%)	LAT (%)	HRV (%)	HUN (%)	PRT	TUR
Emerging	19.12	17.39	11.71	12.35	20.67	14.44	13.58	10.58
Integrative	35.29	34.78	50.45	39.51	31.25	42.22	29.63	33.65
Established	39.71	39.13	30.63	29.63	29.33	24.44	30.86	32.69
Pioneer	5.88	8.70	7.21	18.52	18.75	18.89	25.93	23.08

Table 5: Umbrella categories for the missing technologies derived from inductive content analysis process, where each category was defined by a set of core technologies and the number of total responses mentioning them

Category	Definition	Frequency (n)
Emerging, immersive, and intelligent technologies	Technologies that extend teaching and learning through artificial intelligence, immersive environments, or advanced automation, enabling new forms of cognition, feedback, and experiential learning (e.g. AI, AR, and VR).	139
Subject specific, experimental, and constructive technologies	Discipline focused technologies enabling authentic inquiry, experimentation, modeling, and construction, particularly in STEM and related fields (e.g. labs, simulations, robotics, and maker technologies).	100
Digital learning environments, content, and interaction	Platforms and tools supporting the design, delivery, and interaction of digital learning content, including learning management systems, interactive materials, media creation, and general productivity tools.	98
Digital infrastructure and core classroom technology	Foundational hardware and connectivity required to enable digital teaching and learning, such as devices, internet access, and presentation technologies.	76
Assessment, support, and collaboration	Technologies supporting assessment, feedback, learner differentiation, teacher work processes, and collaboration among students and teachers.	58

AI: Artificial intelligence, AR: Augmented reality, VR: Virtual reality

Table 6: Technologies belonging to each umbrella category reported missing by each teacher group. Percentages are reported as how big portion of teacher's belonging to each group reported a piece of technology missing from each category

Category	Emerging (n=126) (%)	Integrative (n=298) (%)	Established (n=253) (%)	Pioneer (n=133) (%)
1. Emerging, immersive, and intelligent technologies (n=139)	12.70	13.76	20.16	23.31
2. Subjectspecific, experimental, and constructive technologies (n=100)	9.52	11.07	13.44	15.79
3. Digital learning environments, content, and interaction (n=98)	12.70	16.78	7.11	10.53
4. Digital infrastructure and core classroom technology (n=76)	5.56	9.06	10.28	12.03
5. Assessment, support, and collaboration (n=58)	7.94	7.72	4.74	9.77
Empty/no answer (n=240)	29.37	31.21	28.06	29.32
Uncertain or vague about missing tech (n=114)	23.02	14.09	13.44	6.77
No missing technologies (n=55)	7.14	6.71	7.51	5.26

which was the highest share observed for this category across all groups. The least frequently mentioned category for this group was Digital Infrastructure and Core Classroom Technology (5.56%), which was also the lowest share observed for this category across all groups.

For the integrative group, the second most frequently mentioned category was Digital Learning Environments, Content, and Interaction (16.78%), the highest share observed for this category across all groups. The least frequently mentioned substantive category was no missing technologies (6.71%). The proportion of uncertain or vague responses (14.09%) was lower than in the emerging group (23.02%).

For the established group, the second most frequently mentioned category was Emerging, Immersive, and Intelligent Technologies (20.16%), followed by Subject Specific, Experimental and Constructive Technologies (13.44%), and Digital Infrastructure and Core Classroom Technology (10.28%). The least frequently mentioned category was assessment, support, and collaboration (4.74%), the lowest share observed for this category across all groups.

The Pioneer group reported the highest proportions in several categories of missing technologies, including emerging, immersive, and intelligent technologies (23.31%), digital learning environments (10.53%), content and interaction, and assessment, support, and collaboration. At the same time, it had the lowest proportion of respondents reporting no missing technologies (5.26%) and the lowest share of uncertain or vague responses (6.77%).

DISCUSSION AND CONCLUSION

While DigCompEdu provided the conceptual basis for examining teachers' self-perceived digital competence, the observed differences between profiles were interpreted primarily through the lenses of technology-related barriers and TPACK, with TAM serving as a supplementary interpretive perspective. The findings highlighted a continuing gap between policy expectations and classroom realities. Although DigCompEdu and OECD policy initiatives emphasized the meaningful integration of digital technologies into teaching and learning (OECD, 2023; Redecker, 2017), teachers across the profiles reported markedly different technological needs.

The observed differences between the identified profiles presented in Subsection 4.1 may also be interpreted through the TAM (Davis, 1989; Granić and Marangunić, 2019). Although the present study does not directly measure TAM constructs, teachers' self-perceived competence is conceptually related to perceived ease of use. From this perspective, teachers in the lower-competence profiles may be more likely to experience digital technologies as demanding or difficult to manage, which may limit their willingness and ability to identify specific technologies as missing from classroom practice. By contrast, teachers in the higher-competence profiles may perceive digital

technologies as more manageable and may therefore be better able to recognize specific tools that are both pedagogically useful and currently absent from their classroom practice. This supports the prior literature of potentially different support needs (cf. Bauer and Kenton, 2005; Hew and Brush, 2007; Kormos and Wisdom, 2023).

The distribution of the four latent classes varies markedly across the participating countries, indicating that self-perceived digital competence among STEM teachers is not uniformly distributed across European educational systems. Estonian, Finnish, and German participants are least likely to belong to the Pioneer class (5.88–8.70%), whereas Portuguese and Turkish participants are most likely to do so (25.93% and 23.08%), with Latvian, Croatian, and Hungarian participants in an intermediate position (18.52–18.89%). At the opposite end of the spectrum, the Emerging group are most prevalent in Croatia (20.67%), Estonia (19.12%), and Finland (17.39%).

The distribution of the four latent classes appears to vary across the participating countries, which may suggest that self-perceived digital competence among STEM teachers is not uniformly distributed across European educational systems. Estonian, Finnish, and German participants are less likely than participants from other countries to belong to the Pioneer class (5.88–8.70%), whereas Portuguese and Turkish participants are more likely to do so (25.93% and 23.08%), with Latvian, Croatian, and Hungarian participants in an intermediate position (18.52–18.89%). At the opposite end of the spectrum, the Emerging group appears most prevalent in Croatia (20.67%), Estonia (19.12%), and Finland (17.39%).

In digitally mature systems such as Estonia, Finland, and Germany, teachers' broader exposure to advanced technologies may encourage more critical self-assessment. The higher Pioneer proportions in Portugal and Turkey may reflect local reference norms or recent digitalization initiatives, though this remains untestable here. The high proportions of emerging teachers in Estonia and Finland further suggest that self-perceived competence may not track national digitalization levels, and within-country heterogeneity can potentially outweigh between-country variation.

The teachers perceived technology gaps extend beyond access to include pedagogical needs. Many of the reported missing technologies are linked to inquiry-based teaching, interaction, assessment, subject-specific learning, and the development of digital competences. Access or knowledge alone is insufficient for meaningful technology integration. Perceiving a technology as missing requires teachers to relate it to content, pedagogy, learners, and contextual conditions (Koehler et al., 2013; Mishra and Koehler, 2006). Consequently, teachers with stronger digital competence may identify technological gaps more readily because they can better evaluate the pedagogical adequacy of available tools. To further specify the nature of these pedagogical gaps, the five umbrella categories of missing technologies are considered in turn.

Emerging, Immersive, and Intelligent Technologies

The prominence of this category suggests that teachers perceive a substantial gap between current classroom technologies and rapidly evolving digital innovations shaping society and working life. Rather than reflecting a lack of routine digital tools, the responses point to unmet expectations regarding future-oriented pedagogy, such as adaptive learning, intelligent feedback, immersive visualization, and experiential learning. The emphasis on AI in particular reveals that teachers are aware of its growing relevance but feel under-equipped to integrate it meaningfully into teaching, indicating access, or competence gaps. Previous research indicates that the educational adoption of immersive technologies may be constrained by equipment costs, maintenance, and technical requirements (Albishri and Blackmore, 2025). The present results add that such technologies are nevertheless visible within teachers' perceptions of what contemporary classroom practice can include and are aligned with the predictions of Chng et al (2023) on emerging educational technologies. Notably, gaps in this category are most strongly reported by the Pioneer and Established groups, suggesting that awareness of emerging and intelligent technologies is closely tied to higher levels of self-perceived digital competence.

Subject Specific, Experimental, and Constructive Technologies

The high frequency of laboratory tools, simulations, and data collection technologies suggests that teachers miss opportunities for students to engage in authentic inquiry, experimentation, and modeling, while the presence of robotics, maker tools, and games further reflects an interest in constructionist and experiential learning approaches. The reported gaps imply that although curricular goals emphasize inquiry and problem-solving, available technologies do not always sufficiently support these practices in everyday classroom contexts. Such tools can support inquiry, experimentation, visualization, and the construction of representations that are central to STEM learning (Levin and Tsybulsky, 2017; Wellington et al., 2020; Wong et al., 2019). Gaps in this category are most prevalent among the Pioneer and Established groups, indicating that the perception of unmet needs for discipline-specific inquiry tools also increases with self-perceived competence.

Digital Learning Environments, Content, and Interaction

This category reflects teachers' need for technologies that support the design and orchestration of learning processes, not just content delivery. Missing digital learning environments, interactive materials, media tools, and apps suggest limitations in creating engaging, flexible, and student-centered learning opportunities, while the inclusion of modeling and writing tools further indicates that teachers value technologies enabling learners to actively construct and represent knowledge. Overall, this category points to challenges in supporting self-regulated learning, interaction, and multimodal representation, which are increasingly central to contemporary pedagogical approaches. The reported gaps correspond to several

DigCompEdu domains, including digital resources, teaching and learning, assessment, and empowering learners (Redecker, 2017). Interestingly, gaps in this category are most frequently reported by the Integrative group, suggesting a particular sensitivity to shortcomings in platforms and content-related resources among these teachers.

Digital Infrastructure and Core Classroom Technology

The continued reporting of missing infrastructure highlights that basic technological conditions are still not uniformly met, and the observed gaps in hardware, connectivity, and presentation technologies suggest structural inequalities that limit teachers' ability to adopt more advanced tools. Importantly, infrastructure sometimes appears here not as an end in itself, but as a prerequisite for higher-level pedagogical innovation, and the coexistence of infrastructure shortages and demands for advanced technologies underscores uneven digital maturity across educational settings. This pattern corresponds to first-order barriers concerning resources and infrastructure (Ertmer et al., 2012), as well as to broader concerns regarding digital ecosystems (OECD, 2023). Reports of infrastructure gaps are lowest in the Emerging group and highest in the Pioneer group, which may indicate that infrastructural limitations become more visible as teachers attempt more ambitious pedagogical uses of digital technology.

Assessment, Support, and Collaboration

Although this category has the lowest overall prevalence, unmet needs in integrating these technologies imply challenges in making learning progress visible and supporting diverse learners. The comparatively lower frequency may suggest that assessment technologies are already available to some extent, or that their limitations are less visible than those of instructional technologies. Nevertheless, the inclusion of both learner and teacher support tools highlights growing awareness of workload, differentiation, and collaboration demands in digitally mediated teaching. Reports in this category are most prevalent among the Pioneer group, while being lowest in the Established group, suggesting differing degrees of attention to assessment- and collaboration-related tools across profiles.

Beyond the substance of the perceived gaps, their distribution across the four teacher profiles reveals distinct patterns. The relatively low proportion of the Emerging group (5.56%) reporting gaps in Digital Infrastructure and Core Classroom Technology may suggest that teachers in this group are comparatively content with the available hardware. The high share of uncertain or vague responses among the Emerging group (23.02%), combined with the lowest share in the Pioneer group (6.77%), may indicate that the ability to specifically articulate perceived digital technology gaps increases across the latent classes. The lower proportion of uncertain or vague responses in the Integrative group (14.09%) compared with the Emerging group (23.02%) may suggest a more clearly formulated awareness of perceived gaps among teachers in this class.

The Established group's relatively high proportions of missing Emerging, Immersive, and Intelligent Technologies (20.16%), Subject Specific, Experimental, and Constructive Technologies (13.44%), and Digital Infrastructure and Core Classroom Technology (10.28%) may indicate that gaps for this group are concentrated in advanced, subject-specific, and infrastructural technologies rather than in collaborative or assessment-related tools, which may already be adopted to use. The Pioneer group's combination of the highest proportions of reported gaps in several categories with the lowest shares of no missing technologies (5.26%) and uncertain responses (6.77%) may indicate both a heightened awareness of perceived gaps and greater specificity in articulating them. Taken together, the response patterns attributed to each latent class appear somewhat unique while still retaining similarities with neighboring classes.

The nature of perceived barriers may vary across the identified teacher classes. In the lower-competence profiles, especially the Emerging group, the relatively high proportion of "no missing technologies" responses and the lower reporting of specific missing technology categories may indicate more limited awareness of available technological possibilities or less clearly articulated pedagogical needs. This pattern is consistent with second-order barriers, such as lower confidence, narrower pedagogical vision, or uncertainty regarding the role of digital technologies in teaching. By contrast, the Established and Pioneer profiles report more differentiated missing technologies, suggesting a clearer awareness of what is absent from classroom practice. In these higher-competence profiles, first-order barriers such as infrastructure, access, institutional support, cost, and time may therefore become more salient.

At the same time, the pattern across profiles cannot be interpreted as a simple linear progression in all technology categories. Rather than increasing uniformly from Emerging to Pioneer, the profiles differ in the kinds of technologies they identify as missing. Nevertheless, the overall tendency suggests that greater self-perceived digital competence is associated with a more differentiated recognition of unmet technological needs. This interpretation is well aligned with the TK dimension of the TPACK framework, which emphasizes not only the ability to use technologies but also awareness of available tools and their pedagogical potential.

Implications for Professional Development and Educational Policy

These findings also have implications for teacher professional development. If the barriers associated with digital technology adoption differ across competence profiles, then uniform support models may be insufficient. For teachers in lower-competence profiles, professional development may need to focus more strongly on strengthening awareness, confidence, and pedagogically meaningful entry points for technology use. Such support needs to connect technologies with concrete subject content and teaching practices rather than focus exclusively on operational skills, as meaningful integration

requires the coordination of technological, pedagogical, and CK (Jimoyiannis, 2010; Koehler et al., 2013; Mishra and Koehler, 2006). For teachers in higher-competence profiles, support may need to address more structural constraints, such as access to advanced tools, institutional support, and time for experimentation and implementation. Thus, the findings suggest that differentiated support strategies may be more appropriate than one-size-fits-all approaches to digital competence development.

Limitations and Future Research

These findings should nevertheless be interpreted in light of several limitations. First, the study relied on self-assessment data, which capture perceived rather than objectively demonstrated digital competence and might therefore be influenced by overestimation or underestimation bias. Second, the sample was based on non-probability recruitment across participating countries and should not be considered statistically representative of the broader population of European STEM teachers. Third, the interpretation of missing technologies through the lenses of barriers, TAM, and TPACK remains inferential, as these constructs were not measured directly. Fourth the sample also pooled pre-service and in-service teachers, whose interpretations of the open-ended question might differ. Fifth country-level heterogeneity was not modeled directly, although class prevalence was reported by country. Sixth the initial qualitative coding was conducted by a single researcher, and formal inter-coder agreement was not computed.

Finally, the open-ended responses vary in specificity, and some participants provide empty, uncertain, or no-gap answers, which limits the precision with which unmet technology needs can be interpreted. Nevertheless, the study provides useful insight into how teachers with different self-perceived digital competence profiles understand both their own capabilities and the technological absences that shape classroom practice.

AI Use Disclosure

The authors used generative artificial intelligence (Microsoft Copilot and Claude) to assist with language editing, improving readability, and refining the presentation of the manuscript. Original draft, all scientific content, analyses, interpretations, and conclusions were developed, verified, and approved by the authors.

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APPENDIX

Appendix A: Technology umbrella categories, total responses, and associated original codes

Umbrella technology category	Total responses (n)	Individual original codes
Emerging, immersive and intelligent technologies	139	AI related (general); AI; AI as a notetaking aid; AIbased tools; AIbased tool for observing and providing lesson feedback; AI experiment methods; AI in lesson plan making; AI support; AI for task creation; AI to support education; ChatGPT; Gemini; large language models (LLMs); imaging with AI; sensible use of AI in teaching; use of AI in education; attention to AI use in classrooms; AR; AR camera; VR; VR glasses; VR applications bringing nature closer to students; virtual technology; metaverse; and blockchain for educational record storage
Subject specific, experimental and constructive technologies	100	Lab equipment; laboratories; experimental materials; practical activities; sensors; digital measuring devices; digital student measurement tools; measurement and assessment technologies; sensor data processing; spectroscopy equipment; digital cameras and microscopes; photomicrography; data collection and analysis equipment; scientific data analyzers; simulations of phenomena; chemical reaction simulations; ChemLab simulation software; environmental impact simulators; virtual laboratories; online measurement practices; mathematicsrelated tools; GeoGebra; Excel; Maple; Wolfram; statistics applications; Photomath; molecular, physical and biological modeling tools; digital modeling kits; 3D printer and maker technologies; 3D printers; 3D printing software; AutoCAD; TinkerCad; metalpowder 3D printing; robots and programming; Lego Education and Lego robots; robotics; programming in education; educational games and gamification; maps and geodata tools; GIS; ArcGIS; Google MyMaps; and bioinformatics programs
Digital learning environments, content and interaction	98	Digital learning environments; learning management systems; Moodle platform; Mebis (Moodle tools); Canvas offerings; Google Classroom; Teams; Meet; distance learning and hybrid tutoring applications; adaptive learning platforms; autonomous learning applications; selfpaced learning; customizable learning programs; digital task creation; digitizing learning materials as assignments; interactive materials (general); interactive learning; interactive material/media; interactive models; interactive books and smart textbooks; digital books; Genially; Mentimeter; online materials; virtual materials; animations, videos and media; animated videos; animation making; film editing; video creation and documentation; tutorial videos; stopmotion and slowmotion tools; podcasts; music tools; digital recording; apps with teaching content; learning apps; mobile and internetbased applications; Canva; infographic makers; digital posters; presentation software (e.g., Prezi); Padlet; mindmapping tools; and word processing and writing tools (editors, MS Office, and OneNote)
Digital infrastructure and core classroom technology	76	Computers; computers for students; laptops and desktops; teacher laptops; tablets; iPads; teacher tablets; classroom iPad sets; writing tablets for mathematics; stable internet; WiFi; smartphones; mobile phones; students' phones; whiteboards and presentation projecting technologies; interactive whiteboards; smart boards; projectors; document cameras; Apple TV; audiovisual technology; webcams; and inkjet printers
Assessment, support and collaboration	58	Quizzes and questionnaires; digital test creation; Kahoot; Quizizz; Quizlet; Socrative; Wordwall; surveys; quick voting tools; quizbased AI tools; assessment and evaluation systems; learner support technologies; instant and live feedback tools; differentiation tools; accessible technologies; digital support for disadvantaged learners; teacher support tools; classroom management systems; exercise and task banks; plagiarism detection software; voice control of teaching devices; collaboration and cooperation tools; collaborative editing interfaces; digital collaboration platforms; Web 2.0 tools; networks; educational escape rooms; and Trello for project management

AI: Artificial intelligence, AR: Augmented reality, VR: Virtual reality