A Proposal for Assessing Digital Maturity in French Primary Education: Design of Tools and Methods

Christine Michel[1][a] and Laëtitia Pierrot[2][b]
[1]*Techné, University of Poitiers, 1 rue Raymond Cantel, Poitiers, France*
[2]*Cren, Avenue Olivier Messiaen, Le Mans University, Le Mans, France*

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Abstract: The aim of our work is to re-evaluate the concept of teacher digital maturity to make it more operational for diagnosing technology adoption in education and supporting teachers' professional development in the use of technology. To this end, our research adopted a three-pronged approach: 1) establishment of a theoretical framework based on a critical analysis of existing digital maturity models, 2) development of MUME, a unified model of teacher digital maturity based on professional development frameworks, and 3) design and evaluation of a standardized self-report questionnaire to measure teacher digital maturity. This article presents work in progress on the third axis. Using data from a survey of French primary school teachers in 2023, we are comparing various measurement scales to come up with a new approach to diagnosing maturity, including a new scale and new data analysis techniques. The validated questionnaire offers valuable insights into the diversity and progression of uses, contributing to a better understanding of digital maturity and providing a practical tool for assessing contemporary teaching practices.

1 INTRODUCTION

The growing digital transformation within education has propelled it to the forefront of critical educational issues (Antonietti *et al.*, 2023). This is particularly salient in the French context, driven by two key factors: (1) the limited technology integration within primary and secondary teacher practices (Tondeur *et al.*, 2008) and (2) the rapid development and societal implementation of new technologies, posing challenges for teacher appropriation.

Numerous initiatives, encompassing both initial and in-service training and supported by institutional actors, aim to empower teachers to achieve digital maturity (defined as the ability to seamlessly integrate technology into their practices) (Michel & Pierrot, 2023). However, both teachers and stakeholders lament a lack of coordination between these efforts, customization to individual needs, and transparency regarding their impact on digital maturity.

To effectively address this lack of information regarding teachers' actual practices and foster technological integration, European and international educational institutions explore the utility of skills' frameworks. DigCompEdu (Redecker, 2017) in Europe and NETS-T (ISTE, 2017) in the Americas enable the design of diagnostic tools and training structures (Kimmons *et al.*, 2020). This strategy strives to establish a unified approach to directing both initial and in-service teacher training.

A critical analysis of existing frameworks (Michel & Pierrot, 2023) reveals their commendable scope and inclusivity towards various usage scenarios. However, substantial adaptation remains necessary, particularly to incorporate the rapid advance of emerging technologies. Notably, within the K-12 context, the exploration of digital maturity remains underdeveloped. While attempts to address this gap exist (Francom, 2019), they primarily focus on identifying hindering factors and levers, rarely translating into concrete support guidelines for teachers. The absence of a robust conceptual framework within existing research further hinders the identification of effective intervention strategies for teacher development.

[a] https://orcid.org/0000-0003-3123-913X
[b] https://orcid.org/0000-0003-1701-3783

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In a prior study (Michel & Pierrot, 2023), we conducted a hermeneutic analysis of existing models for technology integration and teacher digital maturity in K-12 education. This analysis informed the development of the MUME model, a unified framework encompassing the individual, organizational, and contextual dimensions influencing technology adoption (Harrison *et al.*, 2014). The MUME model, with its non-use to transformation maturity levels, is designed to assess technology integration initiatives across various scales, from large-scale district or regional efforts to targeted support for smaller teacher groups. This paper focuses on the latter application.

To evaluate our model, we investigated the digital practices of K-12 teachers, specifically their use of virtual learning environments (VLEs) and other available digital tools. The subsequent section delves into the literature on teacher digital uses and on the models and tools used to analyze their maturity.

2 LITERATURE REVIEW

2.1 Teaching Practices and Technology

Existing research on technology integration predominantly focuses on tool-driven impacts on learning. However, a gap exists in the investigation of actual teaching practices themselves. While studies investigating into this domain often analyze the pedagogical strategies employed (Lai & Bower, 2019), others emphasize the importance of understanding how teachers leverage technology in innovative combinations (Antonietti *et al.*, 2023). These novel uses are touted to exert a long-term influence on teacher efficacy and responsibility (Griful-Freixenet *et al.*, 2021), while fostering practices that promote student motivation and success.

Virtual learning environments (VLEs) are a prime area of exploration for teachers. In France, despite VLEs deployment since 2006, research suggests use remains confined to basic functionalities (Michel *et al.*, 2021). Among other things, teachers' negative perceptions, such as feelings of inadequacy, lack of professional meaning and time constraints, particularly limit the use of these technologies. Additionally, insufficient support and limited visibility of usage further limit their adoption (Abel *et al.*, 2022).

2.2 Tools for Measuring Digital Maturity

The investigation of teachers' technology use encompasses various objectives, ranging from generating descriptive accounts of their practices to identifying and explaining the factors influencing adoption, associated effects to usage, and even modelling the dynamics of appropriation (Taherdoost, 2018). While large-scale surveys employing questionnaires provide representative insights into population-level trends, their utility primarily lies in generating descriptive studies or models of appropriation (Schmidt *et al.*, 2009). Complementing these quantitative approaches, qualitative case studies offer in-depth explorations of specific technology usage (Hilton, 2016). However, such singular perspectives inherently limit the scope of inquiry, failing to fully capture the multifaceted nature of technology integration in educational contexts. This necessitates the development of multidimensional classification methods that can encompass a broader range of factors, including the intended purpose of technology use, users’ skill levels, perceived benefits and value, and the dynamic evolution of usage over time.

While predominantly focusing on observational studies of technology use, the educational research literature offers several promising tools for measuring digital maturity. The European Commission's "SELFIE for Teachers" project (Redecker, 2017) provides an online self-assessment tool encompassing six key dimensions: pedagogy, resources, assessment, collaboration, professional development, and leadership. Powered by the DigCompEdu skills repository, it guides schools in crafting improvement roadmaps based on their self-assessment results. Antonietti *et al.*'s ICAP-TS scale (2023) focuses on evaluating teachers' technology integration in the classroom, encompassing twelve items that measure student and teacher digital engagement across four cognitive levels. Drawing upon the TPACK framework by Mishra and Koehler (2006), the TPACK.xs scale (Schmid *et al.*, 2020) incorporates the contextual dimension of technology use.

Despite their grounding in validated conceptual models and the resulting ease of data interpretation, the identified scales, like their underlying models, exhibit limitations. They remain fragmented, failing to encompass the full spectrum of teacher professional activity, thereby hindering efforts to provide generalized support (Michel & Pierrot, 2023). Additionally, their context-specific nature raises concerns regarding subjectivity and the comparability of results across diverse settings (Voogt *et al.*, 2013).

3 METHODS

3.1 Dimensions and Items

To comprehensively assess the integration of technology within teaching practices, we constructed a multifaceted questionnaire (Table 1) drawing upon two key sources: (1) validated measurement scales of technology integration in teaching practices: ICAP.TS (Antonietti *et al.*, 2023); SELFIE (SELFIE, 2022) and TPACK.x (Schmid *et al.*, 2020), (2) targeted questions from previous research: FreqNume, FreqENT (Michel & Pierrot, 2022).

Table 1: Questionnaire structure.

Question category	Items
Socio-demographics	*Gender *Age *Seniority *Level of Education *Initial and Technology Training
VLE usage experience	*Technology use before the pandemic *VLE use during the pandemic
Technology knowledge and representations	*General representations of the usefulness of technology for education (TPACK-XK and XK2) *Knowledge of how technology is used in educational contexts (TPACK-XK4) *Digital Competences (DigCompEdu)
Uses	*Technology use frequency (FreqNume) * VLE service frequency (FreqENT) *Classroom usage (ICAP-UseEnclasse), made up of two parts: ICAP-UseEns for teacher usage and ICAP-UseElev for student usage.

To ensure clarity and efficiency, we meticulously translated and streamlined the initial scales while eliminating redundancy across questions. This resulted in a concise questionnaire of manageable length. Additionally, the initial section gathers socio-demographic data and inquiries about the VLE usage experience, providing valuable contextual information for analysis.

3.2 Validation Process

The validation process adhered to the established guidelines outlined by Taherdoost (2016). Content validation commenced with the evaluation of the questionnaire by five subject-matter experts. Their feedback served to refine the content and enhance its overall validity. Additionally, Cronbach's alpha was employed to gauge the questionnaire's internal reliability, specifically assessing the inter-item correlation. An alpha coefficient exceeding 0.70 was targeted to ensure a robust level of internal consistency.

3.3 Data Analysis Method

The core questionnaire, assessing technology knowledge/representations (TPACK-XK, XK2, XK4) and use (UseEnclasse, UseElev, UseEns, FreqEnt, FreqNume), employed 6-point Likert scales recoded for consistency: 0 (never/strongly disagree) to 1 (strongly agree/agree almost daily) for Likert scales and 0 (don't know how) to 4 (regularly do/advise others) for DigCompEdu. This resulted in quantitative data ranging from 0 to 1 and 0 to 4.

Subsequently, descriptive and multivariate statistical techniques were applied to analyze the collected data. K-means clustering, an unsupervised learning algorithm, was used to classify responses for each variable group. This method partitions individuals into distinct, homogeneous clusters based on distance to the cluster's centroid (Ahmed *et al.*, 2020). Smaller distances indicate greater individual similarity to the cluster. Executed on XLstat, K-means identified the central objects representing the individuals closest to the barycenter of each cluster. In coherence with the MUME model, the number of clusters was set to 7. Based on this classification, we characterized each cluster and defined maturity levels for each variable group.

To explore deeper into the data, we employed Principal Component Analysis (PCA), a technique that reduces dimensionality by identifying the least informative dimensions within the dataset. Reduction is achieved by analyzing data correlations and projecting them onto a matrix. This matrix is then used to visualize axes (components) around which the data resides. As the matrix is multidimensional, multiple axes can be extracted, with the most informative ones explaining up to two thirds of the total information. By examining the cosine squared of each variable with respect to each axis, we can determine its relevance: a high value indicates a significant contribution of the variable to that specific axis (Jolliffe & Cadima, 2016).

3.4 Study Context

The CoAI – DATA SIM project seeks to develop data-driven approaches and methods to empower teachers in their individual adoption of digital resources and foster more mature, collaborative practices. This collaborative effort, involving various educational stakeholders, is being piloted in the French academic region of Paris.

In June 2023, we distributed an online questionnaire to all teachers within the academy via their VLE platform. The final analysis included responses from 143 participants, comprising 86 primary school teachers and 18 secondary school teachers. 39 individuals did not respond.

The sample demographics revealed a female majority (101) compared to 22 male teachers; 20 individuals did not disclose their gender. Regarding age, the most prominent group consisted of teachers aged 41-50 (52), followed by those above 51 (43). Individuals under 30 and between 31-40 represented 6 and 23 teachers, respectively; 13 participants did not provide their age. Experience-wise, the majority (88) possessed over 10 years of experience, while 23 had 3-10 years. Five teachers had less than 3 years, and 8 belonged to the "Other" category; 19 individuals did not share their experience data.

To ensure data homogeneity, we focused on the 55 complete responses from primary school teachers, the majority group in our survey. Additionally, we confirm that sub-questionnaires have achieved internal reliability with Cronbach's Alpha exceeding 0.70 (table 2).

Table 2: Sub-questionnaire reliability.

Variable groups	Cronbach's Alpha
DigCompEdu	0,969
UseEnclasse	0,948
UseElev	0,959
UseEns	0,916
XK	0,901
FreqENT	0,924
FreqNume	0,820
XK4	0,741

4 RESULTS

4.1 Different Maturity Level Classifications

The processing approach for classifying maturity levels is the same for all questionnaires. It is detailed in section 4.1.1 only. All other analyses follow the same methodology.

4.1.1 VLE Usage Questionnaire

Table 3 details the average frequency of VLE service use as classified by the K-means algorithm. The questionnaire enquired teachers on the frequency of using 23 specific VLE services for professional activities. Details on response methods and calculations are included in Table 3.

K-means clustering was employed to reduce data dispersion, resulting in the identification of seven distinct teacher profiles (classes). The "non-user" class (Cl0) comprised three teachers with all service usage values at 0, while the remaining 52 teachers distributed across classes Cl1 to Cl6 displayed varied usage patterns. This classification revealed distinct behavioral trends: Cl1 exhibited infrequent service use, while Cl6 demonstrated regular use and exploration of all available services.

Table 3: Primary teacher classes by VLE use.

	Services Classes	Cl0	Cl1	Cl2	Cl3	Cl4	Cl5	Cl6	>0,75	0,75>...>0,25	<0,25	Moyenne
G3	Presences	0,00	0,03	0,02	0,01	0,03	0,04	0,17	0	0	7	0,04
	Pages	0,00	0,04	0,04	0,04	0,03	0,04	0,18	0	0	7	0,05
	Resource reservation	0,00	0,03	0,02	0,02	0,03	0,17	0,17	0	0	7	0,06
	Exercises and assessments	0,00	0,04	0,07	0,11	0,07	0,04	0,19	0	0	7	0,07
	Wiki	0,00	0,04	0,10	0,02	0,07	0,11	0,18	0	0	7	0,07
	Mind map	0,00	0,04	0,04	0,05	0,07	0,10	0,22	0	0	7	0,07
	Collaborative pad	0,00	0,06	0,14	0,02	0,08	0,04	0,20	0	0	7	0,08
	Workstation	0,00	0,04	0,04	0,05	0,12	0,09	0,24	0	0	7	0,08
	Collaborative wall	0,00	0,09	0,06	0,20	0,07	0,05	0,24	0	0	7	0,10
	Logbook	0,00	0,04	0,03	0,04	0,11	0,03	0,17	0	0	7	0,06
G2	Timeline	0,00	0,04	0,06	0,08	0,16	0,10	0,29	0	1	6	0,10
	Library	0,00	0,10	0,14	0,02	0,19	0,21	0,29	0	1	6	0,13
	News	0,00	0,03	0,20	0,13	0,11	0,47	0,51	0	2	5	0,21
	Forum	0,00	0,03	0,04	0,03	0,43	0,04	0,27	0	2	5	0,12
	Agenda	0,00	0,04	0,04	0,17	0,47	0,17	0,45	0	2	5	0,19
	Directory	0,00	0,19	0,03	0,05	0,19	0,58	0,35	0	2	5	0,20
	Skills	0,00	0,40	0,16	0,11	0,54	0,18	0,66	0	3	4	0,29
G1	Documentary space	0,00	0,07	0,41	0,84	0,04	0,59	0,53	1	3	3	0,35
	Multimedia notebook	0,00	0,18	0,75	0,41	0,31	0,54	0,68	1	4	2	0,41
	Messaging	0,00	0,61	0,61	0,26	0,23	0,71	0,93	1	4	2	0,48
	Textbook	0,00	0,04	0,06	0,08	0,55	0,04	0,82	1	1	5	0,23
	News feed	0,00	0,17	0,30	0,60	0,43	0,93	0,84	2	3	2	0,47
	Blog	0,00	0,53	0,24	0,72	0,75	0,82	0,86	3	2	2	0,56
	Number of teachers	3	13	7	6	8	7	11				
	Nb Services adopted	0	0	1	1	1	2	4				
	Nb Services in the process of adoption	0	3	3	4	6	5	9				
	Nb Services not adopted	23	20	19	18	16	16	10				

To investigate deeper into these dynamics, we examined service adoption levels by teacher class. Services with values exceeding 0.75 were considered "adopted," while those below 0.25 were deemed "not adopted." Intermediate values indicated services undergoing adoption. This analysis identified three service groups. 10 services (group G3) have hardly been adopted by teachers. 8 services (group G2) are in the process of being adopted. 6 services (group G1) have been adopted by at least one class of teachers. Interestingly, adopted services primarily served communication objectives, while non-adopted services were more closely aligned with teaching/learning activities. Services undergoing adoption tended to cater to mixed objectives.

Further analysis explored how each teacher class (Cl1 to Cl6) adopts or rejects VLE services. Cl1 exhibited partial adoption of three services (messaging, blog, and skills), indicating an emergent stage with no established VLE practices. Conversely, Cl2 adopted the multimedia notebook and pursued the adoption of messaging, document space, and news feed services. Interestingly, classes Cl2, Cl3, and Cl4 each adopted distinct service combinations (multimedia notebook, document space, and blog). Finally, Cl6 demonstrated the highest service adoption (messaging, blog, news feed, and textbook) with exploration of nine additional services.

These findings highlight a diverse spectrum of VLE adoption strategies among the identified teacher classes. Examining the adopted and non-adopted services within each class reveals distinct levels of digital maturity.

4.1.2 DigCompEdu Questionnaire

Table 4 shows the average skill level according to the DigCompEdu questionnaire adapted for our study. The treatments are the same as above.

Most of these skills correspond to regular practice (level 1) in at least one teacher's class. Group G1 corresponds to skills mastered at expertise level 3 in at least one class, and at level 1 in many others: self-training skills (D1), data protection (D2) or student protection (D6), and the use of technology for certain forms of pedagogy: collaboration, active learning and efficiency gains (D3). Group 4 corresponds to the most difficult skills to acquire, because 4 to 6 classes have not developed them. They correspond to specific pedagogies: problem-solving or experimentation (D3), evaluation (D4), or adaptation/personalization (D5). This structuring makes it possible to qualify skills according to their level of difficulty in terms of expertise: G1 being the simplest to develop, G4 the most complex. We can assume that, over time, all teachers will succeed in developing level 1 skills for groups G1 and G2, but that they will have more difficulty with groups G3 and G4.

4.1.3 TPACK Questionnaire

The mean values per class of teachers' representations of the usefulness of technology for professional practice (XK) are described in Table 5. Class mean values for teachers' knowledge of technology use in their professional context (XK4) are described in Table 6.

4.1.4 ICAP Questionnaire

Table 7 describes the average frequency of digital classroom use by teachers, according to the ICAP scale. The communication uses from the teachers to the learners are adopted by almost all classes (group G1). The collaborative learners centered uses (discuss lessons, working in groups…) are not adopted (group G3). The individual learners centered uses have been adopted by one or two classes or are in the process of being adopted.

4.1.5 Technology Usage Questionnaire

Table 8 shows the average frequency of use of digital services by teachers according to the K-means classification based on the FreqNum questionnaire.

The technologies adopted by almost all classes (group G1) are the classic document production and communication tools: Word, e-mail, search engines, VLE ("ENT") and other design tools. The tools not adopted are serious games and online quiz design applications. Other tools have been adopted by one or two classes or are in the process of being adopted.

Table 4: Classes by DigCompEdu skills.

		Skills / Classes	Cl0	Cl1	Cl2	Cl3	Cl4	Cl5	Cl6	>3	3>...>1	1>...>0,2	<0,2	Moyenne
G4	D3	Use innovative technologies (Robotics, AI, VR) to explore new content and learning experiences	0,00	0,01	0,02	0,18	0,05	0,07	2,20	0	1	0	6	0,36
	D4	Use digital tools to assess learning both formatively and summatively	0,00	0,02	0,02	0,31	0,05	0,40	1,60	0	1	2	4	0,34
	D4	Use digital tools to monitor individual student progress	0,00	0,01	0,02	0,40	0,10	0,47	2,63	0	1	2	4	0,52
G3	D5	Use digital tools to adapt to different levels and paces of student learning	0,00	0,01	0,13	0,84	0,50	0,43	2,13	0	1	3	3	0,58
	D3	Use digital tools to help students solve problems and better understand	0,00	0,16	0,04	0,36	0,50	0,23	2,83	0	1	3	3	0,59
	D3	Use digital tools to help students learn independently	0,00	0,02	0,24	0,49	0,20	0,50	2,83	0	1	4	2	0,61
	D2	Organize digital content so that it is easy to use for students, parents and teachers	0,00	0,09	0,42	0,84	0,80	0,43	1,83	0	1	4	2	0,63
G2	D6	Empower students to use digital tools safely (managing risks to their physical, psychological and social well-being)	0,00	0,01	0,09	0,89	0,70	1,00	2,83	0	2	2	3	0,79
	D5	Take into account the conditions of access to digital tools (material availability, skills, etc.) to ensure a favorable learning environment	0,00	0,00	0,31	0,56	0,30	1,20	2,67	0	2	3	2	0,72
	D5	Take into account students' socio-demographic characteristics to guarantee a favorable learning environment.	0,00	0,03	0,11	0,71	1,25	1,43	2,67	0	3	1	3	0,89
	D5	Take into account students' affective factors (motivation, fatigue, etc.) to ensure a favorable learning environment	0,00	0,00	0,20	0,73	1,75	1,30	2,00	0	3	2	2	0,85
	D2	Use digital tools to find and select digital resources for my courses	0,00	0,39	0,49	0,98	1,45	1,40	2,13	0	3	3	1	0,98
	D1	Reflect on how I use digital tools in my work	0,00	0,18	1,20	0,64	1,45	2,17	2,67	0	4	1	2	1,19
	D2	Use digital tools to create or modify digital resources for my courses	0,00	0,22	0,36	1,07	1,45	1,40	2,13	0	4	2	1	0,95
	D2	Respect intellectual property laws when using digital tools	0,00	0,11	1,00	1,40	2,45	1,83	2,53	0	5	0	2	1,33
	D1	Use digital tools to work with colleagues and others involved in education	0,00	0,69	1,84	1,00	1,50	2,30	2,23	0	5	1	1	1,37
	D1	Use digital tools in my school to communicate with students, colleagues and parents	0,00	1,19	2,07	1,44	2,45	1,63	2,63	0	6	0	1	1,63
G1	D3	Using digital tools for students to work together and communicate	0,00	0,11	0,04	0,44	0,10	0,33	3,00	1	1	1	4	0,58
	D3	Using digital tools for students to produce content and express themselves	0,00	0,13	0,04	0,44	0,25	0,47	3,17	1	1	2	3	0,64
	D1	Use digital tools to help students and teachers reflect on their work	0,00	0,01	0,38	0,47	0,75	0,20	3,00	1	1	3	2	0,69
	D6	Empowering students to use digital tools responsibly and ethically (managing their digital identity, digital footprint, digital reputation, etc.)	0,00	0,01	0,07	0,51	0,15	1,17	3,17	1	2	0	4	0,72
	D3	Use digital tools to help students learn more effectively	0,00	0,52	0,47	0,80	0,60	1,47	3,00	1	2	3	1	0,98
	D2	Protecting students', parents' and teachers' personal information online	0,00	0,10	1,56	0,60	3,00	1,83	2,83	1	4	0	2	1,42
	D1	Using digital tools to learn new things for my work	0,00	0,23	1,00	1,00	0,95	2,33	3,33	1	4	1	1	1,26
		Number of teachers	3	18	9	9	4	6	6					
		Nb Skills developed (level 4)	0	0	0	0	0	0	0					
		Nb Skills developed (level 3)	0	0	0	0	1	0	6					
		Nb Skills developed (level 2)	0	0	1	0	2	3	16					
		Nb Skills developed (level 1)	0	1	5	5	6	11	2					
		Skills under development	0	5	8	18	12	11	22					
		Skills not developed	24	18	11	1	6	2	0					

Table 5: Classes by utility representations (TPACK-XK).

	Utility / Classes	Cl0	Cl1	Cl2	Cl3	Cl4	Cl5	Cl6	>0,75	0,75>...>0,25	<0,25	Moyenne
G3	Collect useful data to help and assess students	0,20	0,28	0,00	0,50	0,00	0,61	0,88	1	3	3	0,35
	Collect useful data to help teachers reflect on and adapt their teaching	0,20	0,32	0,00	0,52	0,23	0,63	0,84	1	3	3	0,39
G2	Help teachers create learning experiences that encourage learner engagement	0,39	0,39	0,00	0,47	0,85	0,74	0,94	2	4	1	0,54
	Help teachers create learning experiences that are more adapted to learners	0,36	0,24	0,87	0,48	0,70	0,59	0,98	2	4	1	0,60
	Facilitate and improve teaching and learning practices	0,38	0,16	0,53	0,64	0,85	0,75	0,90	3	3	1	0,60
	Help teachers create innovative learning experiences	0,40	0,36	0,87	0,58	0,85	0,74	1,00	3	4	0	0,68
G1	Facilitate the creation of digital resources	0,46	0,33	0,78	0,75	0,82	0,91	1,00	4	3	0	0,72
	Facilitate access to a variety of digital resources	0,36	0,71	0,78	0,82	0,82	0,96	0,94	5	2	0	0,77
	Support teachers in their work to access information, communicate and share with colleagues	0,47	0,66	0,92	0,80	0,85	0,82	0,92	5	2	0	0,78
	Number of teachers	7	5	3	12	5	13	10				
	Nb Utility recognized	0	0	5	2	6	3	9				
	Nb Utility being recognized	7	7	1	7	1	6	0				
	Nb Utility not recognized	2	2	3	0	2	0	0				

Table 6: Classes by knowledge of the activity context (TPACK-XK4).

	Knowledge / Classes	Cl0	Cl1	Cl2	Cl3	Cl4	Cl5	Cl6	>0,75	0,75>...>0,25	<0,25	Moyenne
G3	I know about regional and national policies on the use of digital technology in education	0,18	0,20	0,73	0,24	0,71	0,72	0,63	0	4	3	0,49
	I know how my school allocates digital spending	0,13	0,00	0,08	0,11	0,68	0,15	0,94	1	1	5	0,30
G2	I know the school management's objectives regarding the use of digital technology for teaching.	0,30	0,03	0,17	0,72	0,59	0,70	0,93	1	4	2	0,49
	I know how my colleagues use digital technology.	0,30	0,44	0,08	0,71	0,56	0,68	0,89	1	5	1	0,52
G1	I know how to use digital technology for teaching	0,41	0,70	0,78	0,66	0,54	0,76	0,78	3	4	0	0,66
	I know my school's rules on the use of digital technology.	0,28	0,81	0,78	0,74	0,59	0,89	0,85	4	3	0	0,71
	Number of teachers	6	10	3	7	7	12	10				
	Nb Knowledge developed	0	1	2	0	0	2	5				
	Nb Knowledge under development	4	2	1	4	6	3	1				
	Knowledge not developed	2	3	3	2	0	1	0				

Table 7: Primary teacher classes by ICAP use.

	Usages / Classes	Cl0	Cl1	Cl2	Cl3	Cl4	Cl5	Cl6	>0,75	0,75>...>0,25	<0,25	Moyenne
G3	To discuss lessons with their peers	0,00	0,02	0,02	0,02	0,25	0,16	0,59	0	2	5	0,15
	To work in groups on complex problems	0,00	0,02	0,02	0,02	0,25	0,13	0,68	0	2	5	0,16
	To learn in groups	0,00	0,04	0,02	0,02	0,33	0,34	0,63	0	3	4	0,20
	To learn on their own	0,00	0,16	0,02	0,18	0,31	0,44	0,68	0	3	4	0,25
	To work individually on complex problems	0,00	0,02	0,02	0,02	0,01	0,14	0,79	1	0	6	0,14
	To use what they have learned to create new content, such as critical analyses or creative productions	0,00	0,04	0,02	0,02	0,01	0,19	0,75	1	0	6	0,15
	To solve simple problems individually	0,00	0,03	0,02	0,02	0,19	0,31	0,79	1	1	5	0,19
G2	To use what they have learned in exercises, text analysis, etc.	0,00	0,02	0,02	0,02	0,25	0,44	0,79	1	2	4	0,22
	to familiarize themselves with course content	0,00	0,10	0,02	0,67	0,13	0,75	0,68	1	2	4	0,33
	to memorize course content	0,00	0,18	0,10	0,67	0,13	0,75	0,68	1	2	4	0,36
	To explain to students what they need to learn	0,00	0,10	0,69	0,02	0,44	0,82	0,63	1	3	3	0,39
G1	To show students what they are going to learn	0,00	0,12	0,78	0,68	0,64	0,72	0,75	2	3	2	0,53
	To make learning content interesting for students	0,00	0,29	0,89	0,58	0,81	0,86	0,63	3	3	1	0,58
	To explain learning content in an easy-to-understand and detailed way	0,00	0,21	0,81	0,67	0,75	0,86	0,79	4	1	2	0,58
	Number of teachers	14	12	9	3	4	7	6				
	Nb Usages adopted	0	0	3	0	2	5	6				
	Nb Usages in the process of adoption	0	1	1	5	7	5	8				
	Nb Usages not adopted	14	13	10	9	5	4	0				

Table 8: Primary teacher classes by use of digital tools.

	Tools / Classes	Cl0	Cl1	Cl2	Cl3	Cl4	Cl5	Cl6	>0,75	0,75>...>0,25	<0,25	Moyenne
G3	Online quiz design application	0,05	0,11	0,05	0,03	0,06	0,16	0,44	0	1	6	0,13
	Serious games	0,01	0,01	0,03	0,03	0,22	0,41	0,50	0	2	5	0,17
G2	Digital textbook	0,07	0,01	0,14	0,67	0,71	0,35	0,51	0	4	3	0,35
	Video recording / editing application or equipment	0,23	0,46	0,14	0,28	0,34	0,65	0,61	0	5	2	0,39
	Subject-specific applications (math, spelling, etc.)	0,05	0,16	0,14	0,25	0,15	0,30	0,77	1	2	4	0,26
	Other digital resources used in class with students	0,07	0,06	0,03	0,60	0,64	0,15	0,82	1	2	4	0,34
	School management applications (grades, absences, homework, etc.) (Pronote, etc.)	0,05	0,50	0,11	0,58	0,01	0,95	0,70	1	3	3	0,42
	Presentation support applications (PPT, etc.)	0,21	0,36	0,56	0,02	0,57	0,80	0,70	1	4	2	0,46
	Drawing or image editing/retouching applications	0,36	0,46	0,34	0,03	0,50	0,80	0,62	1	5	1	0,44
	Classroom information distribution equipment (TNI, Visualizer, etc.)	0,13	0,51	0,43	0,35	0,82	0,55	0,98	2	4	1	0,54
	Spreadsheet applications (Excel, Calc, etc.)	0,46	0,66	0,60	0,50	0,54	0,76	0,75	2	5	0	0,61
G1	Other digital resources used to design your courses	0,76	0,06	0,08	0,92	0,75	0,20	0,75	4	0	3	0,50
	Information search engine	0,72	0,01	0,95	1,00	0,93	0,90	0,98	5	1	1	0,78
	ENT (Environnement numérique de travail) (Neo, One...)	0,29	0,76	0,82	1,00	0,79	0,75	1,00	6	1	0	0,77
	Online communication applications (Mail, Forum, Blog, etc.)	0,69	0,76	0,95	0,75	0,89	1,00	1,00	6	1	0	0,86
	Word processing applications (Word, Writer, etc.)	0,94	0,71	0,97	0,92	0,93	0,95	0,98	6	1	0	0,91
	Number of teachers	3	18	9	9	4	6	6				
	Nb Tools adopted	2	2	4	5	6	8	9				
	Nb Tools in the process of adoption	5	7	4	7	6	5	7				
	Nb Tools not adopted	9	7	8	4	4	3	0				

4.2 Comparing Classes

To compare all classifications, a Principal Component Analysis (PCA) was conducted on the different classifications obtained using the K-means method for the six groups of variables. Table 9 presents the eigenvalue analysis, Table 10 the squared cosine analysis, and Table 11 the correlation analysis.

Table 9: Eigenvalue Analysis.

	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	2,536	1,283	1,126	0,726	0,579	0,389	0,361
Variability (%)	36,234	18,331	16,080	10,374	8,267	5,561	5,153
% Cumulated	36,234	54,564	70,644	81,019	89,286	94,847	100,000

The first two axes explain half of the information (54%). The first four axes explain 81% of the information.

The analysis of the squared cosines of the variables (see Table 10) allows us to identify the variables that are the most explanatory for the set of constructed classes.

Table 10: Squared cosine analysis.

	F1	F2	F3	F4	F5
Utility (XK)	0,173	**0,347**	0,298	0,018	0,059
Utility (XK2)	0,021	**0,752**	0,001	0,046	0,142
Knowledge (XK4)	0,139	0,068	**0,437**	0,345	0,001
Digital tools uses (FreqNume)	**0,642**	0,016	0,000	0,006	0,165
VLE uses (FreqVLE)	**0,386**	0,000	0,228	0,296	0,001
Skills (DigCompEdu)	**0,683**	0,021	0,001	0,000	0,094
Uses (ICAP)	**0,491**	0,079	0,160	0,014	0,116

Values in bold for each variable correspond to the factor for which the cosine squared is greatest.

The most coherent and explanatory variables for the classifications are those constructed from the questionnaires: « DigCompEdu », « technology use frequency », « ICAP uses » et « VLE use frequency ». These variables explain 36% of the information on the classes and are represented by Axis F1. This axis represents the skills related to the implementation of technology in classroom teaching activities.

The second axis (F2) explains the classifications based on « TPACK question on the perceived usefulness of technology (XK2) » and to a lesser extent « general knowledge about technology (TPACK-XK) ». Axis F2 represents both representations and general knowledge related to technology. The knowledge about the general context of the application of technology suggested in the TPACK (XK4) contributes to a lesser extent in Axis F3.

Table 11: Correlation analysis.

Variables	Utility (XK)	Utility (XK2)	Knowledge (XK4)	Digital tools uses (FreqNume)	VLE uses (FreqVLE)	Skills (DigCompEdu)	Uses (ICAP)
Utility (XK)	**1**	0,248	0,036	**0,362**	0,016	0,224	0,252
Utility (XK2)	0,248	**1**	0,072	-0,065	-0,015	-0,155	-0,235
Knowledge (XK4)	0,036	0,072	**1**	0,252	0,253	0,228	0,030
Digital tools uses (FreqNume)	**0,362**	-0,065	0,252	**1**	**0,448**	**0,503**	**0,404**
VLE uses (FreqVLE)	0,016	-0,015	0,253	**0,448**	**1**	**0,422**	0,205
Skills (DigCompEdu)	0,224	-0,155	0,228	**0,503**	**0,422**	**1**	**0,575**
Uses (ICAP)	0,252	-0,235	0,030	**0,404**	0,205	**0,575**	**1**

Values in bold are different from 0 at significance level alpha=0.05

Correlation analysis (see Table 11) shows that the DigCompEdu classification is significantly correlated with the ICAP classification (0.575), the Frequency of Use of Digital Tools classification (0.503), and the Frequency of Use of VLE Services classification (0.422). General knowledge about technology (TPACK-XK) is significantly correlated with the Frequency of Use of Digital Tools classification (0.362). The Frequency of Use of Digital Tools and VLE Services classifications are also correlated (0.448).

A K-means clustering analysis was performed on the classifications derived from the five methods representatives of F1 and F2. This analysis allowed us to classify teachers according to the intensity of their use of technology (axis F1) and the types of representations they have of technology.

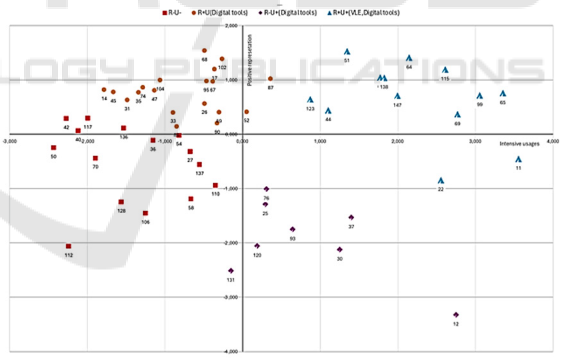

Figure 1: Clustering of Teachers Based on PCA of K-means Classes.

Four groups of teachers were identified (see Figure 1). On the left (respectively right): teachers who use technology to a limited extent (respectively intensively). At the top (respectively bottom): teachers who have positive (respectively negative) representations of the value of technology in the context of education.

It is a classic observation that representations condition uses (for groups R-U- and R+U+), but that they are not a condition for the realization of uses (R+U-). On the other hand, we observe a group of teachers who have negative representations but intensive uses (R-U+).

4.2.1 Respondents' Profiles by Digital Maturity Levels

An examination of each teacher group's composition reveals that those with negative perceptions and limited use (R-U-) demonstrate the lowest awareness of mastering digital competencies (DigCompEdu). This occurs despite their (marginal and restricted) classroom utilization of digital tools (ICAP). Notably, this group falls within the category of non-users of digital tools (FreqNum Cl0 ranking). A representative teacher from this group is a recent hire (less than 10 years' experience) who serves as the digital referent. However, their work in kindergarten (medium and large sections) might explain the limited student exposure to digital tools in their classroom.

Teachers who hold positive views of technology but exhibit limited use (R+U-) acknowledge its various applications (variable XK). While they occasionally employ digital tools beyond the VLE (FreqNum), their classroom integration remains restricted (ICAP). Similar to the previous group, these teachers belong to the non-user's category (FreqNum Cl0 classification). A representative teacher from this group has over 10 years of experience teaching primary school. Despite participating in digital education training and previously using digital tools moderately in the classroom, her pandemic-era use remained limited.

Teachers with negative perceptions but intensive use (R-U+) perceive themselves as competent (DigCompEdu) and recognize the benefits of digital education (TPACK XK). However, they prioritize other digital tools over the VLE, preferring to maintain control over classroom technology use, potentially hindering student engagement (ICAP). This group primarily consists of teachers from the FreqNum Cl2 class. A representative teacher from this group has over 10 years of experience in kindergarten. Before the pandemic, she was a regular user of technology and had participated in relevant training courses.

Finally, the group with the most positive perceptions and intensive use (R+U+) considers themselves digitally literate (TPACK DigCompEdu and XK variables). They regularly integrate digital tools into their own practices and those of their students (ICAP). This group invests less heavily in the VLE and comprises teachers from the FreqNum Cl4 class. The representative teacher from this group has over 10 years of experience working with Cycle 3 pupils. Her pre-pandemic use was moderate, and she likely doesn't require frequent digital training due to her high level of digital literacy.

5 DISCUSSIONS

Our study offers a multifaceted perspective on teacher technology usage and integration. Employing a multidimensional approach, we enlighten various usage dynamics linked to teachers' immediate contexts. Notably, technology use primarily aligns with student interaction and self-training objectives, reflecting teachers' prioritization of these purposes. Further analysis reveals teachers' confidence in their mastery of skills linked to professional commitment (D1) and teaching and learning (D3). Comparing this confidence with technology and VLE use frequency reinforces this finding, as evidenced by the higher utilization of general-purpose digital tools (office automation, search engines, messaging) and communication-oriented VLE services.

By leveraging corpus-based classifications, we identified four distinct teacher profiles based on their technology representations (R) and usage intensity (U). Consistent with our findings, teacher digital maturity manifests in more diverse technology use, with highly engaged teachers exhibiting greater versatility within the available VLE ecosystem. Furthermore, our results echo existing research that links higher self-reported digital competence (DigCompEdu) and positive technology perceptions (TPACK XK2) to increased use of available services, particularly in classroom settings (Abel *et al.*, 2022; Francom, 2019; Tondeur *et al.*, 2008).

These findings highlight key challenges for professional development and teacher support programs. Specialized software remains underutilized and less prominent in teachers' representations (Abel *et al.*, 2022). Additionally, limited confidence exists in D4 skills related to assessment. These areas represent priorities for targeted development efforts. Conversely, the observed adoption of VLE services suggests a promising maturation process. Specific support measures should be explored to facilitate the further integration of these practices.

This study successfully validated our unified questionnaire-based approach for measuring teacher digital maturity. Additionally, the proposed multidimensional analysis approach demonstrated its effectiveness in addressing the limitations often associated with usage observation methods.

The current research acknowledges two limitations. Firstly, the sample size was relatively small. To address this, we plan to compare our findings with a larger dataset of traces of VLE activity. This will also mitigate the second limitation concerning the self-reported nature of questionnaire data.

6 CONCLUSION

This research explores the digital maturity of teachers, a multidimensional concept encompassing teachers' knowledge, skills, attitudes, and practices towards technology. By identifying distinct teacher profiles based on their perception of technology and their usage patterns, we have gained new insights into the importance of considering the immediate context of teachers, as interaction with students and self-training are driving forces in their use of technology. Additionally, teachers' confidence in their digital skills and their positive perception of technology significantly influence the integration of technology in the classroom.

Our results suggest that initial and continuous training programs should focus on the use of specialized tools and the strengthening of assessment practices, while fostering a positive attitude towards technology.

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