Modelling Teachers' Digital Maturity: Literature Review and Proposal for a Unified Model

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Abstract: We present in this position paper how we conducted a literature review on teacher digital maturity models. We extracted 11 models applicable to the field of compulsory schooling. Here, we propose a synthesis of the constituent dimensions of each model and how these dimensions contribute to determine the digital maturity levels of teachers. While our synthesis highlights the diversity of the dimensions included in the models, it also reveals that most of these models provide only a partial picture of technology maturity. Moreover, most of these models focus on the latest levels of maturity, associated with innovative or pioneering teachers, and leave out non- or low digital user teachers, who are well represented in the French context. In the last part of this position paper, we propose a unified model of teachers' digital maturity, called "MUME", addressing these two issues.

1 INTRODUCTION

Digital transformation has become one of the most critical issues in the educational context (Antonietti *et al.*, 2023). These actions are all the more crucial in France, as primary and secondary school teachers show weak technology integration into their practices. Additionally, the potential of technologies for teaching and learning purposes does not depend primarily on the type of technology or its frequency of use, but rather on how such technologies are used to cognitively stimulate and engage students in learning activities (Antonietti *et al.*, 2023). However, the 2020 health crisis has had a stimulating effect on digital practices, even if limited to resource transmission and passive learning (Michel & Pierrot, 2022). Practitioners alongside researchers proposed several models, such as TPACK (Mishra & Koehler, 2006) SAMR (Puentedura, 2012), NETS-T (ISTE, 2017) or DigCompEdu (Redecker, 2017), to describe teachers' abilities, dynamics, levels of integration or digital maturity. However, these models are relatively heterogeneous.

In its common sense, maturity refers to a complete, perfect or ready state of being that is part of a system (Teichert, 2019) In organizational contexts, maturity is the goal that guides many transformations needs, i.e. fundamental changes in strategies, structures and distribution of power, and digital transformation can be seen as a continuous process of employee adoption of a rapidly changing digital offering (Teichert, 2019). In education, maturity models focus on the different dimensions that affect the integration of technologies, particularly the management of digitization actions of structures and teachers' professional activity. Thus, beyond the issues of access, availability and frequency of use, digital maturity considers questions of institutional policy and pedagogy raised by the introduction of technologies (Franklin & Bolick, 2007). Maturity models are also useful for measuring, diagnosing or supporting teachers in their use of technology (Kimmons *et al.*, 2020) More broadly, studying maturity levels leads to approaching the adoption of technologies by combining factors related to the teacher, and professional practice context (Harrison *et al.*, 2014) This requires considering the learner, the teacher and their broader context by collecting data to measure the breadth and depth of technology integration in an institution (Underwood *et al.*, 2007,

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2010; Underwood & Dillon, 2004) This socio-contextual approach to technology adoption differs from work on the expected "good" use of technology and invites us to focus in particular on teachers as "agents of change" or even "leaders" who implement the tool (ISTE, 2017; Leite & Lagstedt, 2021). We carried the current literature review from this perspective.

The multitude of existing models on teachers' digital maturity compete with empirical observations of conceptualized practices, theoretical proposals not tested in the field and others validated empirically. However, these models become the basis for empirical analyses and strategies for teacher training or school diagnostics. These models are also useful for building training curricula or adapting digital tools to the profile of learners, whether students or teachers.

Therefore, our study's objective is to analyse the different maturity models and propose a unified version with a holistic dimension based on our literature review. Our general research question (RQ) is: which model best represents teachers' digital maturity? More specifically, according to which areas to define it (QR1)? According to what levels should it be characterized (QR2)?

2 METHOD

We worked according to a hermeneutic review method (Sackstein *et al.*, 2022) i.e. by identifying: (1) teacher maturity models based on previous systematic literature reviews on models of integration and digital maturity in education (Carvalho *et al.*, 2018; Franklin & Bolick, 2007; Harrison *et al.*, 2014; Kimmons *et al.*, 2020; Leite & Lagstedt, 2021; Solar *et al.*, 2013) and other organizations (Pee & Kankanhalli, 2009; Teichert, 2019) (2) by following all the work cited in the article or citing the article to discover other models until there are no new ones. Only models applicable to the context of compulsory education were selected, i.e. 21 models ((Michel & Pierrot, 2023). We then compared these models considering scope (generic G, or Specific S), the description of the professional activity (Partial P or Global G), the place of the learner (W Weak or Present P), the specification of maturity levels (Yes Y or No N), the usefulness (description De, diagnosis Di, or Support S), the origin of model design (empirical E or Theoretical T) and validation (Yes Y or No N). On this basis, we have chosen the 11 models (see Table 1) that are the most generic in terms of scope and description of professional activity, the most precise in terms of description of levels, and which are based on empirical studies or which have been validated.

2.1 Comparing Maturity Models' Design Features

Most models (see Table 1) consider the context of digital use as a generic element, 2 models specify this context. Five models have the particularity of wanting to consider the entire professional activity of teachers, including tasks outside the classroom (preparation, planning, etc.). Six models cover both teachers' and learners' activity. Four models do not measure maturity levels. These models are primarily descriptive. In the other seven models, the digital maturity of teachers is considered an element of professional development, hence the presence of diagnostic tools or even guides or roadmaps to promote the deployment of technologies. The modelling of the integration of technology in

Table 1: Summary of models according to their main characteristics.

Models	Scope	Professional activity	Learner's place	Maturity level	Usefulness	Origin	Validation
BECTA	G	G	W	Y	Di	E	N
CIT Model	G	G	W	N	S	E	N
DigCompEdu	S	G	P	Y	S	T	Y
ICAP	G	P	P	Y	S	T	Y
ICTE-MM	G	G	P	Y	S	E	Y
LoTi	G	P	W	Y	Di	T	Y
NETS-T	S	G	P	N	S	E	Y
PICRAT	G	P	P	N	De	T	N
SAMR	G	P	W	Y	De	E	N
TIM	G	P	P	Y	Di	E	Y
TPACK	G	P	W	N	De	T	Y

education comes essentially from work based on the observation of practices: 5 of them have a precise theoretical anchoring and 7 models have been empirically validated.

3 MATURITY MODELS

3.1 Models Based on Teachers' Appropriation Dynamics

According to Puentedura, SAMR encourages educators to "pass" levels of education through technology, while maintaining the value and importance of pedagogy and curriculum (Puentedura, 2012). Four steps define the SAMR: substitution, increase, modification and redefinition of the teaching task. The model was developed from observations and without theoretical foundations, but it is widely used and cited in scientific work (Blundell *et al.*, 2022).

The CIT model (Leite & Lagstedt, 2021) considers the collective process of building a group's knowledge (teachers, office heads, principals) and how the culture of the organization can support (or hinder) the integration of educational technologies into school practices. The model has 4 states, rather than steps, to signal that these states are not linear and can be experienced simultaneously by teachers: shock, negotiation, empowerment and exploration.

3.2 Model Based on Teacher's Maturity Dimensions

The TPACK (Mishra, 2019; Mishra & Koehler, 2006) is considered one of the most important models describing teachers' skills for successful teaching with technology. Its added value is not to consider individually the technological (TK), content (CK) and pedagogical (PK) births, but rather their interactions materialized by the overlapping areas (TCK, PCK, TPK). In 2019, TPACK is evolving to include contextual knowledge (XK) on how to integrate organizational and situational constraints (Mishra, 2019). The success of their efforts thus depends not so much on their knowledge of T, P, C and their overlaps, but also on their ability to implement them according to the context.

3.3 Models Based on Teacher Efficacy

ICAP (Chi *et al.*, 2018) differentiates 4 types of learning activities: interactive, constructive, active and passive. It does not specifically describe a level of maturity or ability from the teachers' perspective, but rather the cognitive processes involved in building knowledge structures and reflects learners' levels of cognitive engagement, defined as the investment of cognitive effort in the learning process (Antonietti *et al.*, 2023)

LoTi aims to evaluate the effectiveness of technology implementation through 7 levels (from level 0, for *non-use*, to level 6, corresponding to the level of *refinement*. Conceptually, LoTi describes 5 dimensions (teaching/learning, assessment, student creativity, professional development and digital citizenship). The use of tools and resources in the classroom for teaching and learning is measured using empirically validated tools (Moersch, 1995; Stoltzfus, 2006) that contribute to the professional development of teachers.

3.4 Mixed Models Articulating Educational Efficacy and Maturity Levels

PICRAT (Kimmons *et al.*, 2020) studies how the student is engaged and learns while using technology (PIC, passive, interactive, creative) and how such technology modifies pedagogical settings (RAT, replacing, amplifying or transforming teaching practices), i.e. 9 possible combinations. For each of the categories, the model distinguishes between teaching methods, students' learning processes and didactic objectives.

TIM[1] (Kozdras & Welsh, 2018) appears in the form of a technology integration matrix. It includes 5 levels (entry, adoption, adaptation, infusion and transformation) and 5 features for the learning environment (active, collaborative, constructive, authentic and goal-oriented) that revolve around best practices. It helps the teacher choose how to use technological tools to achieve learning objectives.

3.5 Mixed Models Articulating Skills and Maturity Levels

DigCompEdu was developed to define teachers' digital competencies, for all levels or subjects to be taught, at the European level (Redecker, 2017)

[1] http://mytechmatrix.org and https://fcit.usf.edu/matrix/matrix

DigCompEdu considers professional, pedagogical and learner skills according to 6 domains (themselves broken down into 3 to 6 subdomains) and 6 levels of use in education.

NETS-T (National Educational Technology Standards for Teachers) includes 5 domains describing 4 types of activities (ISTE, 2017). Overall, these standards are designed for self-diagnosis and the creation of educational programs that enable teachers to change their attitudes towards new technologies (Crompton & Sykora, 2021).

3.6 Descriptive Models of Organisational Maturity

The model designed by Becta in 2008 aims to help higher education institutions reach digital maturity through a self-assessment tool around 5 domains (leadership, context, resources, learning support and teaching and learning) and 5 levels for decision-makers and teachers (BECTA, 2008). The model was completed in 2018 (Ristić, 2018) to describe school contexts and cultures that promote the systematized development of technology (integration) by managing and supporting teaching and learning activities.

ICTE-MM (Solar *et al.*, 2013) is a proposal that aims to move closer to international standards such as Capability Maturity Model Integration[2] and NETS-T model. ICTE-MM includes 3 dimensions that can support educational processes (information criteria, ICT resources, and leverage areas). The model offers a self-assessment tool and roadmap to guide school leaders on technology management.

4 TOWARDS A UNIFIED MODEL OF TEACHER DIGITAL MATURITY: MUME

4.1 MUME: Descriptive Domains

We structured the characterization domains of the models by considering the most general integration models to move towards the most specific by integrating all the domains as much as possible (see Figure 1). The models have been integrated in such a way as to preserve the domains and structure of each model as much as possible, as they were initially designed. We carried out various restructurings to articulate the models together in a unified view. When a domain was already present, we chose not to display it in the structuring. Thus, all the domains of LoTi do not appear in the modelling, they are already present in the other models. The 4 structuring models that build this unified view, called MUME, are TPACK, ICTE-MM, DigCompEdu and ICAP. We chose to include in the TPACK only the dimensions that concern the integration of technologies, namely TPCK and XK.

We restructured ICTE-MM and DigComp Edu: learners have been integrated into the areas of DigCompEdu which concern the teacher since it is the actions of the teacher towards the learners that are considered and not the actions of the learners themselves. Thus, these areas are attached under the teacher, in the management of learners. Other DigCompEdu's subdomains (from domain 3) have been restructured around: ICAP pedagogical practices (to integrate TIM and PICRAT) and student management (to integrate the "consulting" subdomain). ICTE-MM's education management has likewise been integrated into the administrators' domain. The dimensions of BECTA could be added on this basis.

The NETS-T domains have been more difficult to integrate because of the role rather than competency structure. We added them as a complementary feature of the finest dimensions of the model, even if their structuring mechanism makes the exploitation of NETS-T difficult in this context. On the other hand, from a UX design perspective, it can provide interesting help for the design of means or support services for maturity.

The proposed unified model has 3 main areas: teachers, administrators and infrastructure. The teaching domain has been reduced to 4 subdomains: professional engagement, digital resources, teaching and education, and assessment. The subdomains "teaching and learning" and "assessment" could be merged, similar to the choice adopted in the NLCC-Edu, but we have chosen to distinguish them given the variety of subdomains of "assessment", in particular the capacities for analysis and feedback from the evidence that falls within the scope of an analyst role.

4.2 MUME: Integration Levels

We perceive many differences when comparing the different models in terms of level. Few models do not mention gradations in practices or skills (such as TPACK or NETS-T). The other models consider

[2] https://www.cmmiinstitute.com/

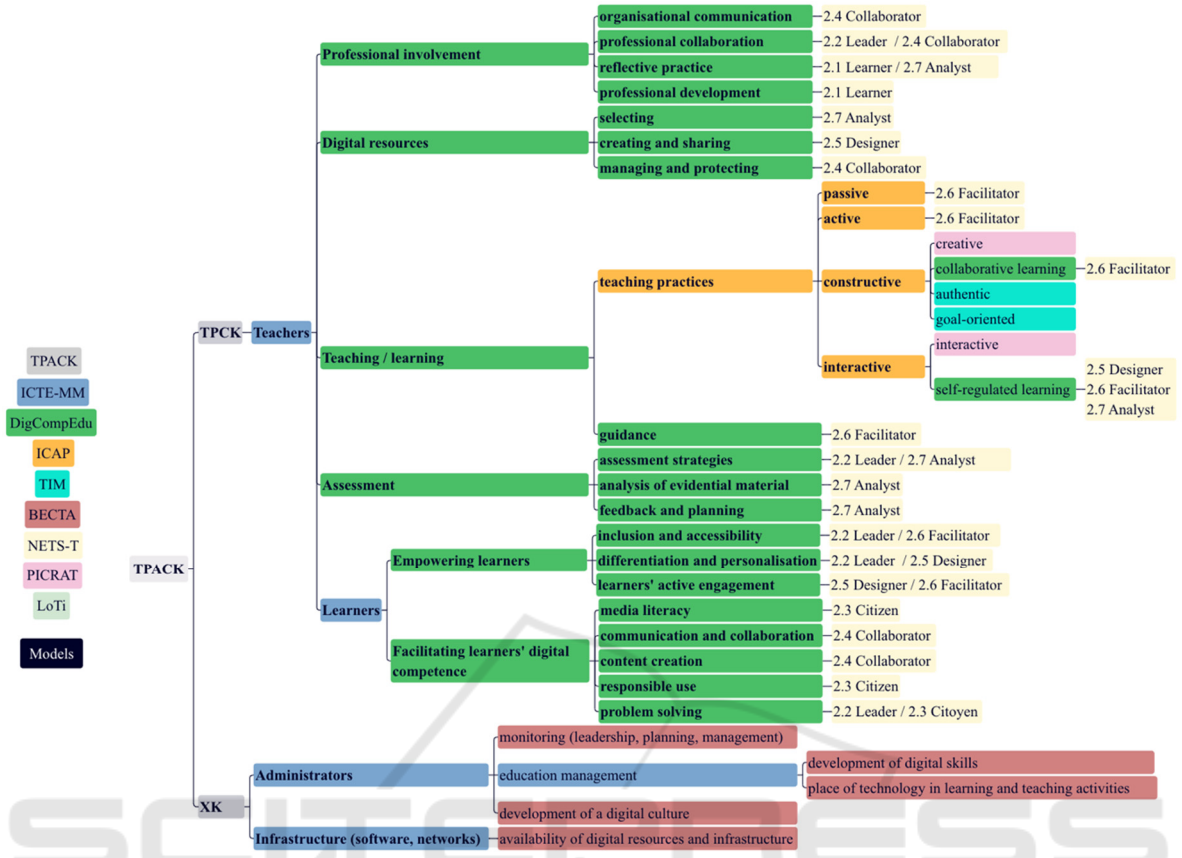

Figure 1: Criteria used from other models to define the MUME.

several levels ranging from 3 to 7. Only DigCompEdu, NETS-T and organizational maturity models consider the leadership role that the teacher can play in disseminating uses and practices through collaboration and sharing. This activity is critical for the dissemination of uses, we choose to keep it. In the same way, only the CIT, TPACK, LoTi and organizational maturity models consider non-use. To the extent that not all practices are instrumented and that the choice not to instrument one's practices is not necessarily a lack of competence among teachers (outside the COVID context), but rather a pedagogical choice, we keep this category and integrate it into the population as a group of non-users.

The models also have different things in common. None of the models considers the TEL used. All integrate a gradation of maturity ranging from an "entry" level, which corresponds to the simplest uses, to a "transformation" level, corresponding to the creation of innovation of use with technology. In most models (SAMR, CIT, ICAP, LoTi, TIM, DigCompEdu, BECTA, ICTE-MM), this gradation considers expertise in terms of techno-pedagogical skills with a core at 4 levels, globally aligned with the definitions of ICAP (passive, active, collaborative, interactive) and a level 5 which corresponds to the ability to innovate towards new techno-pedagogical forms.

If we add a level of "non-use" to Rogers' Diffusion of Innovation (DOI) Model (2003) we can see that levels 6, 5, 3, 2, 1 ("Innovators", "Early Adopter", "Laggard" and "Non-Use") are consistent across all models (see Table 2). Levels 1 and 2 correspond respectively to a non-maturity and an entry into the process of integrating technologies mainly through simple design practices and transmission of training materials. Level 3 is a phase of exploration of possibilities and is embodied in active pedagogical strategies. Levels 4 and 3 (early majority and active majority). Rather, Level 5 is characterized by leadership practices and sharing with other community members, as well as management and analysis. Level 6 is characterized by innovation capabilities and complete mastery of technology integration. Level 4 is less consistent. It is often distinguished in specific models for education in 2 levels: (expert, integrator) for the DigCompEdu,

Table 2: Summary of models according to maturity levels.

Models	Levels description							Levels
DOI	Innovator	Early Adopter	Early Majority		Late Majority	Laggard		5
ICTE-MM	Optimised	Managed	Defined			Developing	Initial	5
BECTA	Maturity	Advanced	Qualified		Autonomous		No maturity	5
DigCompEdu	Pioneer C2	Leader C1	Expert B2	Integrator B1	Explorer A2	Newcomer A1		6
LoTi	Perfecting	Expanding	Integrating	Infusing	Exploring	Raising awareness	Non-using	7
ICAP			Interactive	Collaborative	Active	Passive		4
PICRAT	Transformation		Amplification			Replacement		3
TIM	Transformation		Infusion	Adaptation	Adoption	Entry		5
SAMR	Redefinition	Modification			Augmentation	Substitution		4
CIT Model	Explorer	Autonomous				Negotiation	Shock	4
TPACK	TPACK						TK, PK, CK	1
NETS-T								
Synthesis	Transformation	Development	Integration		Improvement	Substitution	Non-use	6
	Pioneer	Leader	Expert		Explorer	Newcomer	Non-user	6

(Infusion, Integration) for the LoTi, and (Infusion, Adaptation) for the TIM. This level of distinction seems useful to us only to distinguish between interactive and collaborative practices. Indeed, interactive practices are currently underdeveloped and could correspond to an "early adoption" level, but do not correspond to this category's dissemination and leadership capacity. We, therefore, choose first to integrate them into level 4 and will verify the consistency of this choice through an empirical study.

We recommend using a 6-level model:

- Transformation, Development, Integration, Improvement, Substitution, Non-use, considering the characteristic processes,
- Pioneer, Leader, Expert, Explorer, Newcomer, and Non-user, if we consider the roles of the actors.

The corresponding curve is shown in the following figure (see Figure 2), for information only. Rogers' classification was also presented for comparison.

Figure 2: Comparison of diffusion curves of technologies for education for the DOI (Rogers, 2003) and unified model MUME.

5 DISCUSSION AND PERSPECTIVES

This article offers a literature review on teachers' digital maturity. We identified 11 models: 9 models specific to teachers' professional practices (sections 2.1 to 2.5) and 2 models addressing their professional context (section 2.6). Based on a comparative analysis of these models, we propose a unified MUME model, considering individual aspects related to the teacher, and organizational and contextual aspects. This choice makes it possible to use it for global work on the integration of technology in several schools, at a regional or district level, or for specific guidance with a smaller group of teachers, working individually on their practices. In addition, this model has the advantage of covering the entire professional activity of the teacher, rather than just his teaching tasks. The unified model is composed of 6 levels broadly consistent with those of DigCompEdu, Rogers' DOI and ICTE-MM. It also has the particularity of integrating a maturity level 0 (level 1), corresponding to a non-use that we consider a choice of the teacher rather than a hindrance, and to merge levels B1 and B2 of the DigCompEdu. This choice is justified by the fact of proposing a tool that can be mobilized, in the long term, for diagnosis and support for the integration of technology.

The unified maturity model is our first contribution to the observation and analysis of teachers' digital maturity levels. At this point, we identify three perspectives for this work.

The first two are to evaluate this model and to work on tools to make it operational. To evaluate the model, we plan to conduct empirical studies in order to confirm (or reject) the proposals made. These studies will allow us, for example, to verify whether the organization of the different items is meaningful and understandable for teachers or school principals. It will also make it possible to illustrate the current practices of teachers in the different categories and thus to refine the characteristics of each profile presented in figure 2, and possibly to rename them according to a more representative nomenclature. In this regard, technology deployment projects in schools such as those developed as part of projects "Territoires numériques éducatifs" [3] represent a good opportunity. Indeed, these projects, at the level of French departments, consider technology as a factor of systemic transformation. Considering the context and its specificities are essential in this context and we believe that our unified model responds to this challenge.

The second perspective is to build data collection tools to make the model operational for measuring maturity levels. We are presently studying how to build a self-assessment questionnaire as exists for some models such as SELFIE for DigCompEdu, TPACK-TS for TPACK, etc. At the same time, we are studying how to include other modes of data collection (Teichert, 2019; Tomczyk & Fedeli, 2021). Indeed, even if these tools are sometimes empirically validated, they rely primarily on self-reporting. We are investigating how to leverage the potential offered by Learning and Teaching Analytics work based on activity traces with TELs. Our ultimate goal is to propose a blended approach based on these two means for observing and analyzing teachers' digital maturity levels.

The third perspective, which extends the second one, is to conduct field studies to describe and analyze the maturity level of teachers. The description can be done in a global way by drawing the curve presented in figure 2, or in a more precise way by illustrating the practices related to each category presented in figure 1. The analysis will first explain the maturity levels according to the TELs used, the organizational contexts or the personal characteristics of the teachers. In a second step, and using longitudinal analyses, we hope to be able to describe how teachers can move from one level to another.

[3] https://tne.reseau-canope.fr/

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