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# Towards modelling the technology integration in elementary school. A diachronic study of teachers' digital practices during and after Covid-19 lockdown.

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**Abstract.** Different studies have highlighted changes in pedagogical practices in elementary school and several of them question the potential impact of lockdown. The objective of our research is: to analyse the TEL practices of French elementary school teachers in 2020 and 2021, to determine and qualify the levels of technological integration, and to identify the factors explaining the (non-)integration of technology. We conducted a survey and analysed the responses of 572 teachers on their practices and work contexts in 2020 and 2021. By combining a cluster analysis technique on the reported practices and a covariance analysis between the obtained classification and other variables, we identified 3 groups of practices (stabilized, emerging, underdeveloped) and 5 classes of teachers (traditional, interpretative, reproductive, explorer, innovator) according to the way they use technology in vs. outside of the classroom and for traditional vs. constructive learning methods. The impact factors are personal (like the perception of the added value of TEL), contextual (like the equipment offered at the school) and related to the experience of remote work in 2020 (like the feeling of isolation). In the light of our results, we propose recommendations: to foster greater digital integration that goes hand in hand with teachers' professional development and to conduct future diachronic analysis of practices.

**Keywords:** Teaching Practices, Technology Integration, Digital uses, Adoption Model.

## 1 Introduction

The teacher plays a decisive role in the learner's success, through his or her choice of teaching method and ability to manage the class [1]. Teaching methods include verifying the learners' understanding regularly or explicating the course's structure for instance. The quality of classroom management is reflected by continuous supervision of the class or by providing an emulation system to reinforce certain student behaviours. More generally, these teaching practices describe activities implemented to target specific knowledge for learners. The introduction of technology into the classroom transforms these teaching practices. In France, like in other countries, introducing technology into the class is part of an institutional prescription: since 2013, "elements of digital

culture" appear among teachers' expected skills. Teachers must mobilize them to vary didactic content and evaluation format and modalities while contributing to learners' digital skills development.

In this context, studies on the integration of technology in schools focus on teaching practices with technology. We conducted a literature review and observed diverse ways of analysing these practices. First, teaching practices can refer to tasks or activities mediated by digital tools (1.1) or to the use of digital resources (1.2). Furthermore, the recent context related to Covid-19 has contributed to a renewal of the issues related to the integration of technology in schools (1.3). In terms of methods, two main approaches exist (1.4): a descriptive approach, generally associated with qualitative research methods, which complements a rather quantified and modelling approach. Our previous contribution consisted in proposing a digital integration model while considering teachers' professional activity in primary and secondary schools while home-working during the first lockdown of 2020. In this paper, we aim to start from this model to determine how teaching and digital practices evolved, after the 2020 lockdown. Following the presentation of our literature review and our model in this section, we present the study we conducted in 2021 and the main results we obtained in the next ones.

### 1.1 TEL activities in pedagogical practices

We apprehend the role and place of technology in teaching or learning activities using a theoretical framework built on the activity theory [2] completed by the contributions of the instrumental approach [3] on the one hand, and the process described by the didactic triangle [4] on the other hand. Thus, the introduction of a technical object, such as a digital resource, a website, an application, or a service in a pedagogical situation mainly fulfils three educational functions: training on basic digital skills, accessing and searching for information or supporting a learning activity. For this article, we focus on the third function.

574 Belgian elementary school teachers had their practices studied and classified through a cluster analysis [5]. For this purpose, the authors differentiated the declared teaching practices according to "traditional" or "constructivist" teaching methods and obtained four profiles: teachers who declare both traditional and constructivist practices, with high intensity (cluster 1) or low intensity (cluster 4), those who have rather traditional (cluster 3) or rather constructivist (cluster 2) practices. By crossing these profiles with the reported digital uses, they observed that teachers with constructivist practices have greater use of technology. Chuang *et al.* [6] conducted a study on technology integration among 320 Taiwanese primary and secondary school teachers. In this study, integration depends primarily on internal factors, specifically teachers' perceptions of the effects of technology on student learning. In addition, participants chose to integrate technology or not according to how these technologies aligned or not with their practices.

Spiteri *et al.* [7] also examined the factors explaining technology integration in primary teachers' practices, through a literature review that includes 27 studies from 2010 to 2016. From this work, they elaborated a conceptual map with four main dimensions.

The first identified dimension relates to the *school culture*, which favours the development of digital practices when the school allows and supports collaborative work, provides training time for teachers, and integrates projects with technology on a local scale. The second dimension is *teachers' technology knowledge*: which technology, when to use them and why, based on the knowledge of themselves, their students, and the technology. In addition, the technology integration into their practices depends on their teaching experience: longer teaching experience contributes to developing more technical knowledge and therefore using it more optimally. The third dimension focuses on *teachers' attitudes toward digital use*. This dimension focuses on beliefs and perceptions of being effective when using technology. The literature review conducted by the authors shows that these factors do not only depend on the availability of equipment, but also on the importance they attach to it to have beneficial effects on their students (in terms of motivation or academic success for example). The fourth and final dimension concerns *teachers' skills*. To develop the use of technology, the studies cited in the literature review point to their ability to pick constructivist or student-centred pedagogical approaches, particularly through project-based activities, thus echoing the results cited above [5, 6].

In the French context, Dioni [8] notes that there is an "active" minority of teachers who develop their practices to reduce possible inequalities between students. Moreover, there is a distinction in teachers' practices between "digital" practices, relating to the perceived expectations that the school institution has for them, and "personal" practices, which they carry out outside the institution and of which they are not always aware [9]. This tension between institutional (and normative) practices and other personal practices also appears while using digital resources.

## 1.2 Use of digital resources

Digital resources can include static or interactive content. They describe resources that teachers use or transmit in or outside the classroom [10]. Resources include institutional material resources (or curriculum materials), which comply with the curriculum imposed by the educational institution, and those personally produced by teachers (teacher materials) [11]. As with the factors influencing the integration of technology into practice, strong links exist between teachers' beliefs and conceptions (what they think of their role, their mission), their disciplinary knowledge (and their freedom to follow the curriculum or not) and the use they make of institutional resources: these decisions are part of their professional development, and refer to their "sense of professionalism", their ability to adapt and improvise [12].

Teachers mobilize resources inherited from their initial training or more experienced colleagues [13] and "raw" resources extracted and collected from sites or manuals or proposed by groups to build up their corpus of resources.

In Chinese rural schools [14], the authors have observed widespread use of "traditional" resources (digital or multimedia training aids) and a minority of "innovative" resources (video, specialized software for example). Their analysis, based on a two-level model, leads them to conclude that the use of digital resources can be explained mainly on an individual level (the teacher): 80% of the total variance is attributed to

intra-individual differences (mainly age, attitude towards the use of resources, teachers' prior knowledge and teaching experience). In this way, contextual (school) factors are less important. The authors, therefore, recommend considering individual teacher characteristics (or more directly taking teachers into account in digital plans) to facilitate the integration of digital resources into teaching practices.

### **1.3 The Covid-19 context**

School closures imposed by the Covid-19 health context led to numerous studies examining the experience of distance learning motivated by educational continuity. In Scotland, the practices of some 60 primary school teachers were followed from March to June 2020 through in-depth interviews [15]. The participants of the study expressed the feeling of a certain pressure to offer a wide range of digital services, which placed them in a constant search for new tools.

In Spain, the activities of 1403 primary and secondary school teachers during lockdown were collected through a questionnaire [16], distinguishing them according to whether they were part of traditional or constructivist pedagogical approaches and whether they targeted the acquisition of procedural, verbal or behavioural knowledge or their evaluation. Their analysis shows a predominance of traditional type activities, mainly conducted by teachers with little teaching experience; these activities mainly target the acquisition of verbal and behavioural knowledge. Based on these results, they established 4 teacher profiles: the group of "passive" teachers whose activity with technology is the least intense, and mainly according to a traditional approach, the group of "active" teachers, whose activity is more important than that of the passive teachers, still according to a mainly traditional and minority constructivist approach, the "traditional" teachers whose activity is equivalent to the previous group but with a more marked predominance towards traditional activities and the group of "interpretative" teachers whose activity is the most important and mobilizes both traditional and constructivist approaches. Primary school teachers were over-represented in the first group.

In the British context, two studies have examined the resources mobilized during the lockdown of 2020 and 2021. The first one highlights the engagement of students which was higher when schools relied on specific resources for learning, at the school level, notably through VLEs [17]. On the other hand, when comparing the 2020 and 2021 lockdowns, more active strategies implemented (including the use of video conferencing tools) could be observed during the second lockdown [18].

### **1.4 Approaches to accounting for practices**

The works cited in the previous section are divided according to whether they rely on a modelling or a descriptive approach. In the first case, as summarized by Taherdoost [19], the studies were based on models relating to the integration of technology [5, 6, 14, 16–18] and mobilised surveys by questionnaire with a representative aim. In the second case, the authors use more qualitative approaches while intending to conduct more in-depth analyses of the motivations or purposes of the practices, which are less generalizable [8–10, 12, 15].

In a previous study [20], we proposed a model of technology integration that considers elementary and middle school teachers' practices related to the use of a virtual learning environment (VLE) and other digital tools based on data from a questionnaire including closed and open-ended questions and in-depth interviews on the tasks performed during the first lockdown of 2020. This integration model derives from a multidimensional classification [21] to differentiate teachers' behaviours according to the main purposes they were pursuing (activity design, resource delivery, facilitation, verification, communication, and self-study).

Among the 279 primary school teachers surveyed in 2020, the main reported practices with digital tools were motivated by the objectives of resource transmission (integration level 1), to which were added objectives of design (level 2), communication (level 3), self-training and verification (level 4) and finally facilitation (level 5). Most (142/279) of the teachers interviewed are located in class 4 and class 5, with a "pragmatic" [22] use distributed between the services offered by the institution (the VLE) or not and motivated by the imperative need to remain in contact with the students during the schools' closing [23].

### 1.5 Research questions

The analysis of the literature shows that different studies have highlighted changes in teaching practices in elementary school to support a learning activity with the use of digital resources and technologies. Several studies question the potential impact of the lockdown. The objective of our research is to determine how teaching and digital practices evolved in France, after the 2020 lockdown. Our first research question is to determine the levels of technology integration, based on the activities implemented by teachers at school and out-of-school (RQ1). More specifically, what is the contribution of resources found on the internet, transmitted by colleagues or the institution in the integration of TEL? Our goal is also to describe the diversity and intensity of practices in 2021. Our second research question is to explain these levels of digital tools integration (RQ2) based on the individual and contextual factors identified in the previous section. More specifically, the objective is to determine whether the educational experience during the lockdown played a role in the integration of technology in the mainstream context. More broadly, we seek to measure the quality and representativeness of our approach to analyse the dynamics of technology integration in schools (RQ3).

## 2 Study on technology integration

**Context of the study and research questions addressed.** The study is part of the French ministerial program "Territoires Numériques Éducatifs" (Digital Education Territory) launched in September 2020 in the two pilot departments of Aisne and Val d'Oise to contribute to the improvement of educational efficiency with technology in times of pandemic as well as in ordinary times<sup>1</sup>. In this context, the objective of the

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<sup>1</sup> <https://www.education.gouv.fr/les-territoires-numeriques-educatifs-306176>

study is to make a diagnosis of the evolution of teachers' digital practices. We proposed a questionnaire<sup>2</sup>, organized into 4 parts (Personal characteristics, Work context, Practices in 2021/2020/2019, Experience during the Home Confinement) and 108 questions, from January to February 2021 to all teachers in the two departments via their professional email address.

**Participants.** We collected 1224 complete questionnaire responses, these include 572 primary school teachers, representing 10% of each department's total share of teachers. In the Aisne department, 133 responses (out of 1336 elementary school teachers in 2019-20) were mainly from females (114), with an average age of 40 years and 15 years of service. In the Val-d'Oise department, the 439 responses (out of 4181 elementary school teachers in 2019-20) were also mostly from females (374), with an average age of 40 and 13 years of teaching seniority.

**Method.** We used discretization and standardization with the scale data. We identified teachers' technology use strategies over the two time periods by averaging responses on how they performed different academic tasks. We modelled the levels of technology integration (RQ1) using a 5-level K-means classification technique to group teachers according to their declared practices while using technology in and outside of the classroom (TIM21) and during the lockdown (TIM20) by considering questions related to practices over these two periods. We only calculated the TIM20 classification on the 525 responses from teachers who taught remotely during the period. We chose a five-level classification to be consistent with the TIM scale of technology integration [21]. Indeed, this TIM scale considers 5 levels: entry, adoption, adaptation, infusion, and transformation [21]. A matrix describes, for each level, the possible uses of technologies according to the type of learning (active, collaborative, etc.) proposed by the teacher. The TIM matrix does not consider the teacher's administrative and preparation activities. We will consider them as communication, information and design activities [20]. We performed the calculation of K-means on the normalized values. We ordered the obtained classes based on empirical studies on traditional and innovative behaviours identified in the literature.

In addition, we performed an analysis of the covariance (0.05 level of significance) between the TIM21 classification and other variables to identify if there were any explanatory factors (RQ2). The variables considered were: 8 personal variables, the 29 context variables, the practices in 2019 and 2020 (32 variables), and 29 experience variables during the first confinement. We identified a total of 18 variables considered significant and calculated mean values by integration levels for them. We used Excel and XLStat to perform all statistical analyses (bivariate or multivariate analyses).

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<sup>2</sup> Questionnaire :  
<https://techne.labo.univ-poitiers.fr/wp-content/uploads/sites/63/2019/07/questionnaire.png>

### 3 Results

#### 3.1 The current level of technology integration (RQ1)

Tables 1 and 2 show the ratio of teachers who performed different practices during the 2020 lockdown and in normal work mode, according to the TIM20 and TIM21 integration levels and all levels combined. Thus, a value of 1 means that all teachers at that level used that practice. Traditional (resp. constructivist) activities are shown in purple (resp. blue). The communication (resp. information and design) activities are presented in orange (resp. black).

**Table 1.** Percentage of activities during the lockdown according to the technology integration levels TIM20 and TIM21.

Practices during lockdown	TIM	TIM	TIM	TIM	TIM	TIM	TIM	TIM	TIM	TIM	Mean	Mean
	20-1	20-2	20-3	20-4	20-5	21-1	21-2	21-3	21-4	21-5	20	21
Sending homework	1,00	0,93	0,97	0,97	0,93	0,93	0,93	0,97	0,97	1,00	0,96	0,96
Online coaching	0,00	0,70	1,00	0,97	0,99	0,66	0,84	0,86	0,91	0,83	0,73	0,82
Telephone coaching	1,00	0,00	1,00	0,71	0,86	0,57	0,74	0,77	0,75	0,81	0,71	0,73
Prescription for online resources	0,48	0,58	0,76	0,94	0,69	0,56	0,70	0,66	0,77	0,78	0,69	0,70
Prescription for CNED system	0,12	0,04	0,00	1,00	0,49	0,11	0,20	0,24	0,25	0,39	0,33	0,24
Sending self-made resources	0,17	0,20	0,36	0,26	0,49	0,23	0,30	0,33	0,50	0,39	0,30	0,35
Virtual classes (in sub-groups)	0,22	0,19	0,00	0,00	1,00	0,22	0,33	0,39	0,37	0,42	0,28	0,34
Virtual classes (whole class)	0,10	0,15	0,06	0,29	0,33	0,11	0,19	0,16	0,15	0,36	0,19	0,20

**Table 2.** Percentage of activities in regular context according to the integration level TIM 21.

Use in the Classroom, Activity	TIM	TIM	TIM	TIM	TIM	Mean	Use outside the Classroom, Activity	TIM	TIM	TIM	TIM	TIM	Mean
	21-1	21-2	21-3	21-4	21-5			21-1	21-2	21-3	21-4	21-5	
<b>Percentage Of Teachers</b>	24%	25%	25%	19%	7%		<b>Percentage Of Teachers</b>	24%	25%	25%	19%	7%	
Collective visualization of	1,00	1,00	1,00	1,00	1,00	1,00	Programming, scripting	0,74	0,94	0,98	0,93	0,97	0,92
Consultation of resources	1,00	1,00	1,00	1,00	1,00	1,00	Preparation of educational material	0,72	0,97	0,94	0,95	0,97	0,91
Search for information	0,83	0,90	0,77	0,95	0,95	0,88	Communication with parents	0,69	0,88	0,85	0,93	0,90	0,85
Use of exercisers	0,35	0,67	0,22	0,87	0,68	0,56	Communication with colleagues	0,64	0,85	0,92	0,92	0,90	0,85
Individual production	0,24	0,54	0,27	0,66	0,68	0,48	Administrative tasks	0,64	0,86	0,87	0,92	0,92	0,84
Collective production	0,24	0,58	0,24	0,62	0,66	0,47	Evaluation	0,54	0,69	0,94	0,82	0,92	0,78
Communication	0,18	0,42	0,13	0,56	0,58	0,37	Resource - Personal	0,51	0,64	0,84	0,86	0,82	0,73
Students sharing online resources	0,19	0,38	0,13	0,50	0,45	0,33	Communication with institution	0,45	0,74	0,83	0,79	0,77	0,71
Evaluation	0,05	0,04	0,07	0,61	0,37	0,23	Resource-Peers	0,52	0,66	0,72	0,78	0,77	0,69
Programming activities	0,01	0,01	0,00	0,02	0,97	0,20	Resource-Internet	0,45	0,71	0,60	0,83	0,74	0,67
Educational games	0,02	0,15	0,02	0,15	0,29	0,13	Follow-up	0,20	0,45	0,63	0,65	0,82	0,55
							Resource-Institutional	0,20	0,29	0,26	0,34	0,41	0,30
							Correction	0,06	0,04	0,33	0,32	0,49	0,25

According to the TIM20 classification, the practices reported during the lockdown with technology are of the “traditional” type with the transmission of resources and the use of online resources for all levels. These practices are the more accessible ways to integrate technology tools. The level of integration is distinguished according to the mode of follow-up (by phone for class 1 and by email for class 2), the type of resources used for the design (online resource for class 3, institutional for class 4 and self-produced for class 5). These differences are less visible in 2021 with a more homogeneous behaviour at all levels which means that these practices are becoming more widespread. The strongest progression in 2021 is online coaching, which can be considered as an adaptation of practices over the period. Constructive activities such as virtual classroom facilitation or the design of personal resources are progressing but remain low. These practices are being adopted. The use of institutional resources will decrease in 2021 to the benefit of resources created by teachers.



The integration of technology tools is quite segmented in 2020 (see Table 1) with specific choices for each class (identifiable by 0's and 1's on some lines) whereas it is more inclusive and cumulative in 2021: the technologies integrated by class 2 are those of class 1 plus others, etc. In the regular context (see Table 2), the most developed activities are “traditional” learning activities in the classroom: whole class or individual resource presentation and information retrieval. Technology tools are then used more and more according to the TIM level for activities outside the classroom: designing scenarios or digital resources, communicating with parents or other teachers and administrative tasks (class 2), evaluating students, and improving personal resources (class 3), self-training through internet research or collaboration between colleagues (class 4), monitoring and correcting students' work (class 5). Teachers in classes 4 and 5 also use technology for classroom activities for constructivist activities: exercise, individual and collective production of documents, communication between students (class 4), and programming and educational games (class 5). Uses outside of the classroom follow a regular progression. On the other hand, uses in the classroom, such as collaborative and constructivist TEL uses, are stopped for classes 1 and 3. Further studies must be done to understand why these practices can't be regularly adopted. Uses of exercisers and programming software seem to be good leverage for new teaching practice transformations.

### 3.2 Explanatory factors

Of all the variables tested, only 18 variables were significant to explain the composition of the TIM integration classes21: 5 items were related to the added value of technology, 4 items to the context (the school identification, the fact that the school equipped the teacher with a computer and the classes with peripheral devices, and that the teacher himself had devices) and 9 items to the experience during the lockdown (previous experience, integration level TIM20, reorganization of the work at school and professional isolation). These variables are marked in bold in Table 1 and Tables 3-5.

**Personal variables.** Table 3 shows the mean values for the perceived usefulness of technology, overall (“benefits of technologies”) and for different educational purposes.

**Table 3.** Average score attributed to technology value according to the TIM21 level.

Perceived value of technologies	TIM21-1	TIM21-2	TIM21-3	TIM21-4	TIM21-5	Mean
Benefits of technologies	0.81	0.85	0.86	0.89	0.95	<b>0.87</b>
Improve the quality and diversity of documents	0.67	0.83	0.77	0.84	0.89	<b>0.80</b>
Promote openness to the world	0.65	0.69	0.68	0.78	0.76	0.71
<b>Train students to the use of technologies</b>	0.50	0.64	0.63	0.78	0.84	<b>0.68</b>
Educate students about issues affecting technologies	0.42	0.57	0.54	0.59	0.79	<b>0.58</b>
Train students to information retrieval	0.39	0.57	0.51	0.63	0.74	<b>0.57</b>
Allow individualized and personalized work for students	0.43	0.45	0.44	0.61	0.79	<b>0.55</b>
<b>Facilitate group activities and collaboration between students</b>	0.25	0.31	0.43	0.44	0.76	<b>0.44</b>
<b>Facilitate students' personal work at home</b>	0.23	0.28	0.32	0.40	0.68	<b>0.38</b>
<b>Stimulate students' creativity</b>	0.14	0.21	0.26	0.38	0.53	<b>0.30</b>
Allow the inclusion of disabled students	0.16	0.23	0.23	0.36	0.47	<b>0.29</b>
<b>Improve the evaluation of learning</b>	0.06	0.11	0.21	0.24	0.71	<b>0.27</b>

All teachers feel that technology is useful (0.87/1) especially for improving the quality of documents (0.8) and openness to the world (0.71). Overall, in the higher TIM21

levels, the feeling of usefulness is greater, which corroborates the link between the feeling of usefulness and the uses. More specifically, 5 criteria play a role in integration. Some are shared by all classes, such as training students in technology, while others are mainly identified by class TIM21-5, such as facilitating group or homework, improving evaluation or stimulating creativity. With averages of 0.68, 0.44 and 0.38, it seems quite easy to convince teachers on the first 3 criteria (train students, facilitate work at home or in a group) by giving them examples of uses. The last two (creativity and evaluation) seem to be further away from the teachers' values and practices.

**Contextual variables.** The level of equipment is relatively similar for all teachers. However, they feel that they are better equipped to work at home than at school. The fact that the school provides the equipment is a factor in technology integration, mainly concerning peripherals devices: a printer and hard drives at home and an interactive whiteboard (IWB) at school. In only 23 schools out of the 94, the technology integration exceeds the level TIM21-4 in a significant way. Further study is needed to understand the reasons for this by analysing the school culture [8].

**Table 4.** Average score attributed to equipment according to TIM21 integration level.

Context	TIM21-1	TIM21-2	TIM21-3	TIM21-4	TIM21-5	Mean
Home equipment provided by the school	0.31	0.43	0.33	0.42	0.51	0.38
Satisfaction home equipment	0.59	0.63	0.62	0.65	0.58	0.62
Home : Digital interface	0.35	0.41	0.41	0.39	0.49	0.40
Home : Tangible interface	0.02	0.02	0.02	0.02	0.11	0.02
Home : Peripheral devices	0.27	0.34	0.37	0.37	0.44	0.34
Satisfaction school equipment	0.49	0.57	0.49	0.55	0.57	0.53
School : Digital interface	0.30	0.42	0.33	0.42	0.51	0.38
School : Tangible interface	0.05	0.09	0.08	0.22	0.18	0.11
School : Peripheral devices	0.20	0.35	0.33	0.41	0.48	0.33
School network satisfaction	0.41	0.54	0.46	0.54	0.38	0.48
Use of personal equipment at school	0.53	0.54	0.66	0.61	0.62	0.59
School Id	0.24	0.25	0.25	0.19	0.07	0.20

**Experience variable.** Several practice variables had a significant impact on technology integration: uses before COVID (in bold in Table 5) and activities during lockdown (in bold in Table 1). Using technology before COVID favours integration with 0.76 and 0.88 in TIM21-4 and 5. As described earlier, having carried out in 2020, the traditional type of training activities (sending homework, prescribing resources found on the Internet) consolidated carrying out traditional activities in 2021 but did not allow the introduction of constructivist teaching activities in the classroom. On the other hand, the fact that teachers were designing their own resources in 2020 had an impact on out-of-class use: they found it easier to search for information on the Internet or to communicate with other teachers. Similarly, having accompanied students on the phone or by email in 2020 helped the teachers in 2021 to follow students online.

Unlike the studies cited by Spiteri *et al.* [7], skills did not impact technology integration. Teachers report being poorly trained (0.25) but having a proficient level of technical or teaching skills (resp. 0.65 and 0.69) and not having suffered from a lack of skills in 2020 (0.32 and 0.03) while having built useful skills during this time (0.86).

The professional isolation linked to the lockdown and the changes induced in the way of working at school have also significantly influenced the integration of

technology, especially for classes 3 and 4 (Table 5a). Overall, teachers believe that the way they work at school has changed (Table 5b). Teachers communicate more with parents (0.81 and 0.73). To a lesser extent, they share their resources and practices more (resp. 0.63 and 0.67) and exchange with each other (0.56, 0.44, 0.40) or help each other (0.40). Some behaviours are specific to class 5 teachers: they engage in more collaborative practices with joint preparation activities (0.67), which significantly impacts technology integration, and they participate in virtual teacher communities (0.63).

**Table 5.** (a) Average score attributed to experience according to TIM21 integration level and (b) focus on “change at school” variable

Experience	TIM21-1	TIM21-2	TIM21-3	TIM21-4	TIM21-5	Mean	Perceived changes in work at school	TIM21-1	TIM21-2	TIM21-3	TIM21-4	TIM21-5	Mean
Satisfaction with initial training	0.23	0.21	0.24	0.19	0.37	0.25	More frequent exchanges with parents	0.71	0.82	0.84	0.88	0.88	0.81
<b>19 : Use before COVID</b>	0.52	0.66	0.46	0.76	0.88	0.66	Advice to parents on supporting schoolwork	0.71	0.72	0.73	0.75	0.92	0.73
20 : Lack of technical skills	0.36	0.33	0.33	0.38	0.22	0.32	Sharing resources	0.67	0.40	0.81	0.67	0.88	0.63
20 : Lack of pedagogical skills	0.03	0.02	0.03	0.03	0.06	0.03	Sharing practices	0.67	0.27	0.71	0.63	0.63	0.57
20 : Lack of digital resources	0.19	0.23	0.27	0.19	0.19	0.21	More frequent exchanges with the school	0.44	0.53	0.74	0.50	0.80	0.56
21 : New COVID skills	0.54	0.58	0.60	0.74	0.64	0.62	Mutualization of resources	0.67	0.20	0.58	0.50	0.93	0.49
21: Usefulness of new comp	0.83	0.78	0.89	0.90	0.90	0.86	More frequent exchanges with administrative information	0.33	0.44	0.48	0.52	0.52	0.44
<b>20 : Professional isolation</b>	0.30	0.31	0.48	0.41	0.31	0.36	Distribution of printed materials	0.33	0.39	0.48	0.47	0.44	0.42
<b>21: Change in work at school</b>	0.08	0.11	0.33	0.34	0.42	0.26	More frequent exchanges individually	0.44	0.33	0.51	0.29	0.67	0.40
21 : Change in work outside of school	0.05	0.11	0.25	0.27	0.24	0.26	More mutual aid	0.33	0.27	0.56	0.35	0.53	0.38
21 : Change in parent relationship	0.67	0.72	0.84	0.85	0.69	0.77	<b>More collaborative preparation</b>	0.11	0.13	0.44	0.50	0.67	0.30
21: Technical Skills	0.53	0.63	0.66	0.69	0.72	0.65	Participating in virtual communities	0.00	0.40	0.39	0.37	0.63	0.29
21: Teaching Skills	0.64	0.65	0.69	0.72	0.77	0.69	Distribution of computer materials	0.02	0.06	0.09	0.07	0.08	0.06

## 4 Discussion

**Emerging student-centred approaches over the period.** To answer the first research question (RQ1), our study shows that overall, teachers have greater use of technology in ordinary times. Considering practices' nature and evolution, three groups appear: stabilized practices, emerging ones, and underdeveloped ones. Stabilized practices, mainly related to "traditional" pedagogical approaches: communicating and preparing/planning/designing activities outside the class and, disseminating resources in the classroom. This result is consistent with similar studies cited above [5, 6, 12]. Stabilized practices are, most of the time, combined with diversified emerging practices enhanced by the lockdown: tasks in relation to resource work, evaluation/follow-up and communication with the school. In 2021, teachers used few institutional resources and more resources shared by peers, found on the Internet or made by themselves. We need to examine whether containment has helped in setting up a new framework that limits institutional/normative "pressure" [8, 9]. Finally, underdeveloped practices include the use of educational games, communication and collaboration activities and we must analyse if this observation falls under the pragmatism approach identified in Spanish primary school teachers [16].

Different dynamics of technology integration can be observed. In classes 1 and 3, the teachers prefer to integrate technology first in activities that do not directly involve the students (preparation of lessons, communication with parents, administrative tasks) and then in activities that take place in the classroom. Class 1 is a group with a "traditional" profile [16] characterized by low activity while group 3 attaches a lot of importance to

the preparation of material and is similar to a "reproductive" profile [16]. Classes 2, 4 and 5 are "interpretative" [16]: teachers use traditional and constructive practices (i.e. student-centred approaches) according to the situation. Class 4 performs more self-training to diversify the modes of implementation, they can be described as "interpretative explorers" while class 2 renews themselves less and are rather "interpretative followers". Class 5 uses technologies for more complex practices such as programming and are "innovators". Unlike the innovation curve, which is bell-shaped, the curve of technology integration in schools (see Figure 1) follows a horizontal asymptote. The traditional group remains large. To make this group evolve, it is necessary to train them mainly in the practices of groups 2 and 3.



Fig. 1. The curve of technology integration in schools [22]

We identify two leverage effects that should be considered. First, it is essential to offer a limited and rationalized range of technology to teachers, who in any case will concentrate on those they consider most suitable for them and their students [6, 7, 14, 15]. For this reason, we recommend involving teachers as much as possible in the choice of technology and providing design training for pedagogical activities. Second, the stabilization and emergence of "personal" rather than institutional practices mark a milestone in the professional identity of teachers [12]. It appears that lockdown has opened up the possibility for more transfers of practices developed outside the classroom. To maintain this openness, institutions should recognize and value the activities of teachers who deviate from the normative framework by encouraging peer sharing during in-service training.

**Factors explaining technology integration (RQ2).** Our results are in line with the work on the perceived usefulness of technology that precedes its actual use [6, 8]. Referring to the traditional/constructivist classification of Tondeur *et al.* [5], teachers are aware that technology is useful in general but not to support constructive learning or train students in digital skills. Our study shows that skill variables do not impact technology integration, which contrasts with previous work [7]. Teachers reported having been poorly trained, but still having good technical and pedagogical skills. They declared that they had learned during the COVID, that they had not experienced a lack of skills, yet they only partially integrated them into their practices, mainly for traditional activities. An incorrect self-evaluation of their skills can explain this paradox: having insufficient training, they consider that the personal efforts made to integrate technology are adapted. It is therefore essential to provide teachers with examples of constructive practices with technology to help them identify their limits in terms of technical and pedagogical skills and to encourage the implementation of these practices. In

addition, it would be interesting to accompany them in a professional certification such as the PIX<sup>3</sup>, as it is required for students.

We believe that the dissemination of information is not a highly effective way to raise teachers' awareness of the added value of technology or the implementation of practices. Teachers are much more sensitive to direct communication with expert teachers, present in schools or in online communities. Thus, workshops or awareness-raising would be much more effective in supporting digital-related changes, in particular, integrating more constructive practices in the classroom. The context in which technology is deployed also influences the integration of technology, mainly the availability of equipment: to promote this integration, it seems necessary to systematically provide teachers with personal computers so that they can use them at home. In this way, the development of practices in and out of the classroom [10] can be facilitated, as well as the work of monitoring and developing effective resources [11]. Classrooms should also be systematically equipped with broadcasting and interaction devices such as IWBs or visualizers to match the most common activities of primary school teachers.

**Analysis of our approach to measuring TEL integration.** To answer the third research question (RQ3), our approach, which combines a classification of practices and an analysis of the covariance, allowed us to see how teachers deploy strategies to integrate these technologies into their practices both outside and inside the classroom. In addition to observing an intensification of its usage that increased between 2020 and 2021, we were able to follow the evolution and stabilization of certain practices, while identifying the factors explaining these dynamics. Although initially responding to different objectives (the previous study focused more on the use of the VLE), the study presented here complements our previous results to provide an overview of the main practices conducted among French primary school teachers. In addition, our approach allowed us to cover practices that were not necessarily included in the TIM. While the matrix focuses on practices in the classroom, the analysis of our data highlights behaviours related to uses mainly in the classroom (classes 2, 4 and 5) or outside (1 and 3). This constitutes a step forward in the analysis of teachers' activity in relation to the TEL continuum. The method can nevertheless be questioned on different aspects.

*Data collection and analysis.* Some variables, such as the use of software or the websites used, are not well described in this study, which is more focused on the technical means. The analysis of the "other" open-ended questions in the questionnaire should be carried out to identify the software, in particular the exercises, and the Internet resources that teachers most often choose to use. Moreover, our study highlights a lack of information about certain phenomena. The surprising results regarding teachers' self-assessment of skills suggest that these data are biased or inaccurate. To have a more accurate measure of skill levels, it would be preferable to use PIX-type certification scores, but they are not used in France. It would also be interesting to refine the questions based on the expectations of school directors or government agencies. Similarly, we have identified that some schools have specific characteristics that hinder the integration of TELs, but we do not know whether these are organizational, material or

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<sup>3</sup> <https://pix.fr/>

related to the socio-demographic characteristics of students and families. To continue the study, we propose to analyse the 92 complementary answers of the school directors.

*Diachronic analysis of practices.* Does a diachronic analysis of different practices observed show an evolution in practices? For each practice, no: some are abandoned while others emerge. It is therefore impossible to compare strictly the same practices. However, the classification method allows teachers to be grouped by class of practices and our study shows that comparing classes makes sense. Diachronic studies can accurately follow the life cycle of established practices by questioning teachers regularly about how they are carried out but can also include or eliminate others because they are innovative or abandoned. A preliminary study in selected schools, in the form of interviews and focus groups, would allow for this and for the inclusion of possibly emerging impact factors that the questionnaire could measure on a larger scale. We have conducted a series of 50 interviews with teachers, principals, parents and children. We will analyse them soon to complete the results of this study, but also to identify those new factors that could be useful to observe in other future studies.

## 5 Conclusion

We conducted a study to determine the levels of technology integration, based on the activities implemented by teachers at school and out-of-school in 2021, one year after the confinement. Through the analysis of 572 primary school teachers' responses to a questionnaire, we identify 5 classes of teacher profiles: traditional, interpretative, reproductive, explorers, and innovators. We found also that the curve of digital tools integration in school is not following the classical innovation curve. It is characterized by horizontal asymptotes representing a large group of traditional teachers. Emerging student-centred approaches are also more intense than in the classical curve. We identify 3 main factors explaining technology non-integration: a lack of value in using technology to support constructive learning, a lack of equipment especially in a classroom, and a lack of collaboration culture between teachers in school. Our study shows that skill variables do not impact technology integration, which contrasts with previous work. This is explained by a lack of professional certification in digital uses. We propose various perspectives to promote technology integration and refine the approaches to measuring TEL integration.

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