Training pre-service teachers to enhance digital education

Teachers must be digitally competent at the beginning of their career. The main aim of this paper is to study whether specific training is necessary to enable pre-service teachers in Catalonia with the required level of teacher digital competence (TDC). Three cases are discussed. In the first case, TDC is self-assessed among first-year pre-service teachers (N=1166). In the second, TDC is assessed among second year pre-service teachers who received specific training (N=33). The third case measures TDC among third-year, pre-service teachers without any specific training in TDC (N=151). Results reveal that pre-service teachers who are given specific training in TDC get better scores in the assessment compared to those who do not receive training. Practical implications suggest that formative assessment processes are necessary as part of specific training in TDC in higher education curricula, must be practical and address the methodological aspects of TDC.

Introduction

All aspects in personal development have been affected by the digitalisation of society, including leisure, education, work, etc. Nowadays, digital technologies determine how we live, learn, interact and work (Adams et al., 2017). Professional and personal activities have been transformed by technological advances, which are bringing new possibilities for a more proficient personal development. The confident and critical use of digital technologies is vital to avoid becoming a digital misfit (Ilomäki et al. 2016). Future citizens need to develop their digital competence so they can adapt to the constant technological development that is changing the society in which we live (European Commission, 2018a).

Every government education policy must be responsible for training future citizens to take active part in a digital society. Hence, teachers need to be digitally competent enough to use digital technologies, not only for personal use, but also in their professional activity. The priority of the Digital Education Action Plan is to facilitate educational innovation and, as a result, higher quality in education (COM, 2017; European Commission, 2018b).

In the 2030 Agenda and the Sustainable Development Goals (SDG; United Nations, 2015), UNESCO (2018) recognises the importance of teachers being able to

use digital technologies to improve and innovate in the learning environment used by students. In particular, using technology in education can clearly help to make progress in SDG 4 (Quality education) and SDG 10 (Reduce inequalities). Today, the digital gap is no longer technological but cognitive (Tello, 2007); therefore, teachers have become largely responsible for educating in a way that reduces this cognitive digital gap.

Furthermore, the current post-pandemic context forces teaching-learning process to rely on digital technologies, while also giving greater urgency to the need for evidence on the impact of the use of digital technologies in infant and primary education. Two inevitable consequences became evident in schools after the COVID-19 quarantine period in Spain: the digital gap and insufficient development of the teachers' and students' digital competence (XXXXX, 2020). Lessons learnt from the context of COVID-19 should help us to rethink education when the health crisis ends (Zhang et al., 2020).

Keeping this in mind, in 2018 a research project funded by the Catalan government was launched by the six public and two private universities from the Catalan university system that teach infant and primary education teachers. Based on the existing frameworks and previously designed TDC assessment tools and using them to measure both the self-assessed and the objective level of TDC development of pre-service teachers, this project had a twofold aim: 1. Establish a certification model for the TDC level at the end of the pre-service teacher's degree; and 2. Design a training course for pre-service teachers to reach this certification properly by the end of their initial studies. The main aim of this article is focused on the second goal of the project, that is, to determine the need for a specific teacher digital competence (TDC) training that enables pre-service teachers in Catalonia to access the labour market with the required TDC level. In order to reach this goal, three different practical cases focused on the assessment and self-assessment of pre-service teacher digital competence are presented and discussed.

Discussing the results from these case studies will allow us to determine whether it is necessary to design a course for developing teacher digital competence in pre-service teacher training as a hard skill to ensure that future educators will be able to develop the digital competence of their students, and therefore, reduce the cognitive digital gap (Tello, 2007).

Digital technology and educational processes

In recent decades, digital technologies have had a higher impact on educational processes in general, and in particular in primary education. However, it is also true that the lack of clarity and coherence in some definitions and the highly diverse nature of digital technologies have led to false generalisations about the effectiveness of using technology in education (Means et al. 2013; Mahmud, 2018). Furthermore, there is not always evidence to suggest that the use of digital technologies lead to an adequate acquisition of this new knowledge (Siemens et al. 2015; XXXXXX, 2020).

The results of international studies such as PISA and TIMMS suggest that digital technologies do not have a key impact on improving student's learning outcomes, attitudes, or time devoted to learning. However, the frequency of use of digital technologies is a key factor for improving learning (Hu et al. 2018; Petko et al. 2016).

The impact of digital technologies on education also depends on external factors that prevent them from being used. The factors that limit the effectiveness of digital technologies include the lack of appropriate infrastructure (Eickelmann & Vennemann, 2017), technological access and support, little investment (Williams & Beam, 2019) and, more importantly, the inadequate and insufficient training in digital competence of teaching staff (Hillmayr, et al., 2020; Williams & Beam, 2019). In addition, it is important that practices and paradigms in teacher training in technology use are often not focused on pedagogical aspects (Gros & García-Peñalvo, 2016) and the amount of time that has to be invested is miscalculated (Eickelmann & Vennemann, 2017). In terms of the internal factors, it has been found that the beliefs, attitudes and expectations of the teaching staff are often not conducive to applying digital technologies (Eickelmann & Vennemann, 2017; Lai & Bower, 2020, Williams & Beam, 2019).

It is clear that, in order to achieve positive results in student learning, motivation and involvement, and before digital technologies can be incorporated into educational processes, we need to design a pedagogical strategy, plan, make a cost-benefit analysis and focus on providing teachers with practical training (Hershkovitz & Karni, 2018). These programmes have to be practice-based, and teachers need to be provided with support, while students are encouraged. In this post-pandemic context, hybrid forms of teaching/learning are mandatory, and require a reappraisal of the instructional design,

and an extra investment of time and effort to move towards a more active, student-centred approach (König et al., 2020).

Frameworks for defining Teacher Digital Competence

Teacher digital competence (TDC) is a multidimensional construct. Different frameworks worldwide aim to define and measure their dimensions and levels of development: The UNESCO (2018) framework as the international model of TDC, DigCompEdu (Redecker & Punie, 2017) at a European level, and in Catalonia, there is the framework of the Catalan Government (Generalitat de Catalunya, 2018). According to the Catalan framework, pre-service teachers at the end of their university degree should be at a first level of TDC to access the teaching profession. Although each framework uses its own conceptualisation, an in-depth analysis of the content of their dimensions and levels of development reveals a clear correlation among all of them (See Table 1). According to the framework defined by the Generalitat de Catalunya (2018), there are four levels of development of competence: Level 1: "basic", Level 2: "intermediate", Level 3: "expert", and Level 4: "transformational". Pre-service teachers, at the end of their degree studies, must have the first level of TDC development to be able to join the educational system. Level 1 is the level defined for a novice teacher and is, consequently, the one that universities must ensure that their students and future teachers have. XXXX (2015), based on all the existing TDC frameworks, built a rubric for measuring this competence among pre-service teachers, and further defined TDC as "a set of capacities, abilities and attitudes that the teacher must develop in order to incorporate digital technologies into his or her professional practice and development" (XXX et al., 2019; p.73). Then, COMDID is defined (from the Catalan words COMpetencia DIgital Docente [Teacher Digital Competence]) as the framework for TDC that emerges from the study of all the existing TDC frameworks (see column 1, Table 1). Finally, COMDID-A and COMDID-C were designed and validated as instruments for self-assessment and assessment of this multidimensional construct (XXXX et al., 2021).

Table 1. Relationship between the dimensions of the TDC frameworks.

COMDID Framework (XXXX, 2015)	**Teacher Digital Competence (Generalitat de Catalunya 2018)**	**DigCompEdu (Redecker & Punie, 2017)**	**ICT Competency Framework for Teachers (UNESCO, 2018)**
Dimension 1. Teaching, curricular and methodological aspects	D1. Design, planning and teaching implementation	A3. Digital pedagogy A4. Assessment and feedback A5. Student empowerment A6. Facilitate student digital competence	A1. Understanding the role of IT in educational policies A2. Curriculum and assessment A3. Pedagogy
Dimension 2. Planning, organisation and management of digital technology resources and spaces	D2. Organisation and management of digital technological resources and spaces	A2. Digital resources	A4. Use of digital competences A5. Organisation and administration
Dimension 3. Relational aspects, ethics and security	D3. Communication and collaboration D4. Ethics and digital civic behaviours	A1. Professional commitment A5. Student empowerment A6. Facilitate student digital competence	A1. Understanding the role of IT in educational policies A4. Use of digital competences
Dimension 4. Personal and professional aspects:	D5. Professional development	A1. Professional development	A1. Understanding the role of IT in educational policies A6. Professional learning for teachers

Assessment and certification of TDC in the initial training of infant and primary education teachers

The importance and specific weight of certification has increased considerably in the last 30 years. It is often a requirement for finding a job and for developing a professional career and has even generated tension between standardisation and flexibility. These two viewpoints have been defended and attacked by their proponents. Those in favour of standardisation tend to argue in favour of highly structured training in competences, based on rubrics and indicators (Laitinen, 2012), while those in favour of flexibility focus the process on the knowledge that individuals can construct and develop and do not believe that an associated accreditation process or evidence that knowledge has been acquired are necessary. Knowledge has a value in itself, is part of learners' growth and documentary proof is not required (Lang et al. 2015). From our

perspective, the assessment required for accreditation and certification must be based on the general framework that has been previously introduced, and evidence of the whole process of TDC development must be collected at different times with different strategies and tools.

More than two decades of experience by some universities in assessing and certifying competences reveals that the process of measuring competences in terms of learning is by no means straightforward. Moreover, it is not always economically viable if the model is a flexible or a mixed one, since it requires a considerable investment of time and effort (Lang et al., 2015). The Catalan university system structures this assessment and certification process in two phases. This study focuses on the first phase, which uses standard assessment tools applied in all education faculties to determine whether last-year pre-service teachers have achieved the first level of TDC. The second phase adds to this standard assessment a student e-portfolio providing the evidence obtained on the development of TDC and supplements the quantitative result of the standard assessment tools and will not be discussed in this paper.

In the Catalan context, well-respected professions have specific processes of accreditation and certification that are a requirement for professional practice. For example, doctors must complete a five-year degree programme, pass an exam (identical all over Spain) and then do a specialised training programme if they aim to work in the public health system. Graduates in law must do a master's degree after their bachelor's degree which qualifies them for professional practice as lawyers.

Infant and primary teachers must complete a general four-year bachelor's degree because one of the consequences of adapting university degrees to the European Higher Education Area was the elimination of specialities. In particular, the "New Technologies Applied to Education" speciality was removed and now teachers are trained as infant or primary education teachers, without the opportunity to be trained or develop their Teacher Digital Competence (TDC). In Catalonia, there is also a double degree that allows students to become infant and primary education teachers. The guidelines issued by the Spanish Ministry of Education on undergraduate curricula are the same throughout the country. However, the fact that there is no specific training is a problem that does not only affect Spain. As Caena pointed out (2013, p. 8) "Although Ministers have not adopted a complete list of the competences teachers require, they have agreed that, as a minimum, teachers should have a specialist knowledge of the subject(s) they teach, plus the necessary pedagogical skills to teach them, including

teaching to heterogeneous classes, making effective use of digital technologies, and helping pupils to acquire transversal competences."

It is in this context that, as teachers and researchers, we have tried to respond to the challenge of designing and developing a framework for the development, assessment, and certification of Catalan pre-service teachers. We now present three practical cases that measure self-assessment and the final assessment of TDC and then discuss how these results highlight the need to design and develop specific training for developing pre-service teachers' digital competence in Catalonia, using the framework COMDID presented in Table 1. Finally, the proposal of this training course will be detailed for each of the four dimensions of the TDC in order to help pre-service teachers to achieve the first level of TDC as established by the Catalan Government (Generalitat de Catalunya, 2018).

Case 1: Self-assessment of first year, pre-service teachers' digital competence in Catalonia

This first study focuses on the population of students in the first course of initial teacher training in the Catalan universities with a bachelor in teacher training (xxxx University, xxxxx University - xxxx University, University xxxx, Universitat de Barcelona, Universitat xxxx, Universitat xxxx and Universitat xxxx). Participants voluntarily answered the self-perception test (COMDID-A) through an online form. The study was ethically approved by the Catalan Government and the online questionnaire complied with all the ethical restrictions of Spanish Law. Each university collected the responses corresponding to their institution, at the time of the reception events for first-year students, or during the first days of the start of the first year. Data were collected between October 2018 and June 2019. Of the 1166 students who answered the online questionnaire, 1030 students completed all the items. A total of 19% of the students were male and 81% female. Their average age was 19.4 years (SD = 3.3), ranging from 17 to 45 years. Concerning the specialization or type of education of these first-year students, 492 were studying to become infant teachers; 270 (28.51%) were studying to become primary education teachers, and 185 (19.54%) were studying the two degrees at the same time. Although not random, this sample is representative of Catalan first-year teacher training students. The response rate of the universities was not the same, but the distributions the respondents' gender, age and qualifications for admission to university

were in accordance with the national distribution of first-year student teachers in Catalan education (Generalitat de Catalunya, 2018).

To measure the self-perception of TDC in this sample of first year pre-service teachers (see Table 2), the self-assessment version of COMDID, called COMDID-A, was used. This instrument was designed and validated (XXXX, 2018; XXXX et al., 2021) based on the dimensions and development levels of TDC, as explained in the previous section. The final version includes 22 Likert-scale items that students must rate (1: totally agree; 10: totally disagree) according to their self-efficacy. An example of an item: D3.2. "I encourage that all students have access to and can use digital technologies with the intention of compensating for inequalities". In order to measure the four dimensions of this professional competence, six items measure D1. Teaching, curricular and methodological aspects; five for D2. Planning, organisation and management of digital technological resources and spaces; five focus on D3. Relational aspects, ethics and security; and finally, six for D4. Personal and professional aspects, (see column 1, Table 1). Results are given in a percentage for each dimension. COMDID-A was implemented as a formative assessment of TDC because it gives individual feedback on the results after the test has been sent, and it helps participants reflect on their self-assessed level of TDC.

Table 2. Descriptive statistics on self-assessed TDC for students from first-year pre-service teachers in Catalan Universities

	Dimension 1. Teaching, curricular and methodological aspects	**Dimension 2. Planning, organisation and management of digital technology resources and spaces**	**Dimension 3. Relational aspects, ethics and security**	**Dimension 4. Personal and professional aspects**
Mean	71.88	72.40	77.07	75.80
Standard Deviation	13.33	13.28	12.65	13.69
Minimum	5.00	2.00	6.00	0.00
Maximum	100	100	100	100

The results in Table 2 show the differences among the four TDC dimensions in the sample with no prior experience or training in TDC. In particular:

D1. Teaching, curricular and methodological aspects: This dimension shows the lowest average scoring, although it is higher than 70%. This may be because this

dimension is closely related to teaching practice and pre-service teachers in this sample do not have any prior teaching experience as they are first-year students.

D2. Planning, organisation, and management of digital technology resources and spaces: first-year students rated themselves with high scores, like D1, but not as high as for D3 and D4. This can also be due to their lack of teaching experience; as they are first-year students, and they do not have practical teaching experience.

D3. Relational aspects, ethics and security: in this dimension the students assess themselves as more competent (77%). This may be because, as primary and secondary school students, they were aware of the importance of combating cyberbullying, plagiarism, etc.

D4. Personal and professional aspects: in this dimension students evaluate themselves higher than 75%. However, their perceptions cannot be realistic. We will explain the reasons for this bias in the discussion of the three cases.

Case 2: Assessment of TDC in a group with specific TDC training in the double degree of infant and primary education.

This case is focused on a group of 33 students in the second year of pre-service teacher training in a Catalan university: Universitat xxxxxx. A total of 6% of the students were male and 94% female. Their average age was 19.7 years (SD = 1.2).
This group was trained specifically in TDC. During the second year of their bachelor's degree, they have a specific compulsory annual subject of 12 ECTS entitled "Organisation of School Space, Materials and Teaching Skills." This subject uses the methodology of project- and problem-based learning. TDC is trained transversally and is present in all the students' activities. After the training, the participants passed the assessment test on TDC: COMDID-C, developed and validated by XXXX et al. (2019). This tool has 88 questions or practical cases, distributed as follows: 44 true/false questions, 11 for each dimension of the TDC; and 44 multiple choice questions, also distributed among the four dimensions. It gives results in percentages (%) for each dimension and its results can be compared to the self-assessment results from COMDID-A.

Below we briefly describe how the pre-service teachers in this sample are trained by taking part in innovation projects:

- Bridging projects. Different schools in the area take part (about 40 every year). Pre-service and in-service teachers work together to develop digital materials in response to the needs expressed by the participating schools.
- The Simul@b project. In an environment that simulates a school in 3D, pre-service teachers solve problems that are typical of a school context. In one of the activities, they have to design a school and a classroom in response to a particular situation or problem. Finally, as part of a simulated competition, they have to present the architectural, pedagogical and organisational proposals of the school they have designed using multimedia resources and the social networks.
- The TDC research project. Students in this sample follow an assessment process similar to the one that will be used in Catalonia in 2025, where all the pre-service teachers will be assessed through the standard process (initial self-assessment, final objective assessment, and a final certification).

Table 3. Highlights of the initial teacher education programme in TDC for 2nd-year teacher trainees.

Dimensions of TDC	**Teaching and learning activity**	**General objective**	**Learning outputs / evidence**
Dimension 1. Teaching, curricular and methodological aspects, Dimension 2. Planning, organisation and management of digital technology resources and spaces & Dimension 3. Relational aspects, ethics and security	Contextualised teaching proposal and design of educational digital materials.	Draw up in collaboration with practising teachers a teaching plan and all necessary materials to respond to real needs expressed by schools in the same area as the university.	Teaching plan and materials. Recording of sessions in the schools.
Dimension 1. Teaching, curricular and methodological aspects, Dimension 3. Relational aspects, ethics and security & Dimension 4. *Personal and professional aspects*.	Symposium for exchanging educational experiences among professionals.	Discuss the most important educational experiences in a symposium for future teachers and teachers currently working in participating schools.	Poster of the symposium. Publicity on the social networks.

Dimension 1. Teaching, curricular and methodological aspects Dimension 2. Planning, organisation and management of digital technology resources and spaces Dimension 3. Relational aspects, ethics and security Dimension 4. *Personal and professional aspects*.	Learning capsule using a 3D simulation environment.	Design a teaching experience based on a simulated situation in a school and classroom context.	Learning capsule.
D1, D2, D3 and D4	The classroom as a learning environment using a 3D simulation environment.	Design the physical space of a classroom and its technological resources based on a simulated situations.	Audiovisual presentation of the classroom
D1, D2, D3 and D4	Innovative school educational project	Draw up an innovative school project based on an analysis of the context.	Executive report. Promotional audiovisual.

In Table 4 it can be seen that those who had been given specific training in TDC during their training passed the test satisfactorily (79.4% of students got more than 70 out of 100 which is the cut-off point). This means that nearly 80% of the pre-service teachers in the sample (after the work experience programme) have reached the level of development needed to start their professional practice.

Table 4. Descriptive statistics on TDC assessment for second year, pre-service teachers from the double degree, after specific training in TDC.

	Dimension 1. Teaching, curricular and methodological aspects	**Dimension 2. Planning, organisation and management of digital technology resources and spaces**	**Dimension 3. Relational aspects, ethics and security**	**Dimension 4. Personal and professional aspects**
Mean	73.14	87.01	77.08	70.55
Standard Deviation	11.82	89.53	13.21	12.70
Minimum	41.08	66.70	42.60	43.83

Maximum	88.92	100	97.50	93.75

The average of all four dimensions is higher than 70% because the students were in the second year of their degree and had just completed some specialised training in TDC. In particular, for each dimension:

D1. Teaching, curricular and methodological aspects: The second-year students of the double degree were less competent in this dimension than the other dimensions, even though the average was higher than 70%.

D2. Planning, organisation and management of digital technological resources and spaces: The second-year students of the double degree had a high TDC level. In fact, their level for this dimension is the highest. This could be because D2 is closely related to teaching practice. Even though the students do not have any experience in teaching, the training they had received and the content of the TDC programme had a positive impact on their level in this dimension.

D3. Relational aspects, ethics and security: in this dimension the students are very competent (77%). In this case, this may be more because in their prior primary and secondary school studies, participants had been aware of the importance of combating cyberbullying and plagiarism, etc.

D4. Personal and professional aspects: in this dimension the level of the group is also around 70%. This result points to the need to reinforce the training of these aspects during their future training in TDC.

Case 3: Assessment of TDC in a group without specific TDC training, in infant and primary education.

The third sample consisted of 151 pre-service teachers in the last (fourth) course of their bachelor's degree. The TDC level was measured in a similar way to case 2. All participants answered the COMDID-C at the end of the academic year of their initial teacher training programme. It is important to remember that, unlike the group in case 2, these students were not given any specific training in TDC. In the first year of their pre-service training, they had a compulsory subject (Communicative Skills) in which they worked on content related to Dimension 1 (tools for teaching and learning), Dimension 3 (communication tools) and Dimension 4 (digital identity) of TDC. During the rest of the degree, training in the use of the digital technologies is limited to the practicums,

where they work in infant and primary schools. Therefore, whether students can develop their TDC or not depends solely on the digital maturity of the schools and the tutors they are assigned to.

A total of 26% of the students in this sample were male and 74% female. Their average age was 23.1 years (SD = 2.4), ranging from 20 to 33 years. In this case, the COMDID-C was implemented as a final assessment in TDC, because it gives individual feedback on the results after the test has been sent. This makes all pre-service teachers who are about to start their teaching careers aware of their real TDC level and understand whether they are ready for a future process of assessment and further certification.

Table 5. Descriptive statistics on TDC assessment for the last year, pre-service teachers from education bachelor's degrees, without specific training in TDC.

	Dimension 1. Teaching, curricular and methodological aspects	**Dimension 2. Planning, organisation and management of digital technology resources and spaces**	**Dimension 3. Relational aspects, ethics and security**	**Dimension 4. Personal and professional aspects**
Mean	66.91	80.73	68.56	62.47
Standard Deviation	13.95	13.92	14.38	12.99
Minimum	32.08	37.60	31.80	34.83
Maximum	97.92	100	100	93.75

As shown in Table 5, scorings in each dimension are lower than those in cases 1 and 2. And in particular, only 55.3% of students scored above 70% and passed the assessment in TDC. Therefore, almost half of the pre-service students in their final year of initial training would not be able to obtain a certificate that shows that they are digitally competent. The average score for the group was 69%.

In this last case, although the sample consists of students that are at the end of their bachelor's degree, their TDC training was "unstructured". Participants were not given any specific training in TDC, although they had been in work experience programmes in schools. Work experience programmes in schools are quite different in terms of their use of DTs. Averages of the four dimensions varied between 62% and 80%.

D1. Teaching, curricular and methodological aspects: This is the second dimension at which the fourth-year students of the infant and primary school education bachelor's degree are less competent, even though the mean score is higher than 70%.
D2. Planning, organisation and management of digital technological resources and spaces: Participants' level of TDC is high. Their level in D2 is higher than the other dimensions and compared to the other cases. This high level is because many of the students had already had some teaching experience.

D3. Relational aspects, ethics and security: The students are less competent in this dimension (68%), which includes areas such as plagiarism, etc. Although the students are not very competent in this dimension, their mean score in D3 is higher than in D1 and D4. In addition to specialized training, although during their degree students are introduced to D3 areas, more practical work is necessary and maybe we should learn from our experience of the double degree.
D4. Personal and professional aspects: the level of the group in D4 is very low. In fact, a score of 62% means that students are not competent enough to start their professional careers (<70% cut-off point). Therefore, students should be better supported during their teacher training and should probably start their teacher training work experience programme earlier.

Lessons learnt from the three cases

We should first remember that the general aim of this article was to determine the need for a specific teacher digital competence (TDC) training that enables pre-service teachers in Catalonia to access the labour market with the required level of TDC development. To fulfil this aim, the results of the three cases on TDC assessment were analysed in relation to each of the four dimensions of this professional competence. This allowed us to understand particular needs in the design and implementation of TDC training among pre-service teachers in Catalonia.

It should be pointed out that the distributions by age, gender and qualifications to access higher education explained above mean that these three cases can be used to discuss the Catalan context (Generalitat de Catalunya, 2018).

A review of the three cases shows that the results of the first-year students' TDC self-assessments are higher than the scores obtained in the objective TDC assessment of the other two groups. This may be because students tend to perceive themselves to be more competent than they really are (Flannelly, 2001; Foster et al., 2017). Therefore,

the results show that, from the very beginning of the bachelor's degree, pre-service teachers need some sort of constant and specific training and guidance to help them become aware of their real TDC development level, and intentionally improve this competence during their pre-service education.

However, cases 2 and 3 show that current training depends largely on "luck" and this is not enough for these future teachers to meet the current, post-pandemic educational system requirements. Although pre-service teachers are given some training as part of a compulsory subject that sporadically works on D1 (tools for teaching and learning), D3 (communication tools) and D4 (digital identity), there is no specific programme to develop TDC. During the rest of the bachelor's degree, training in the use of digital technologies for teaching is limited to the *in-service* periods at schools. Therefore, whether students can develop their TDC or not depends entirely on the digital maturity (expertise) of these schools. In order to advance with the TDC certification at the end of the pre-service training, research outcomes suggest that specific training in TDC covering all its dimensions, should be urgently applied in all Catalan universities.

Dimension 1. Teaching, curricular and methodological aspects has the lowest scores in both self-assessment and assessment. This dimension considers that first-year students have little or no prior teaching experience; nevertheless, the average score at the end their studies is still lower than the acceptable minimum level (70%) and, regardless of having some sort of teaching experiences at schools, students need more training in this dimension. A first-year programme focused on this dimension could be useful to help students become aware of their lack of competence in the aspects related to pedagogical and curricular digital technologies.

D2. Planning, organisation and management of digital technological resources and spaces.

In case 1, first-year students show a lower scoring in this dimension due to their lack of teaching experience and the first-year subjects focus on the other TDC dimensions. However, students in cases 2 and 3 who have received theoretical and hands-on training show positive impacts in this dimension. This highlights this dimension's close relationship with the in-service teaching practicum.

D3. Relational aspects, ethics and security:

This dimension reports first-year students self-perception as highly competent in TDCs, but second-year students are assessed higher on average. This evidences the work carried out by primary and secondary education on aspects related to Digital Competence, particularly in terms of plagiarism, cybersecurity, ethics, etc. (Hatlevik & Christophersen, 2013). Moreover, fourth-year students who are not given any specific training fail to reach the 70% cut-off point in the assessment of this dimension (68%). Therefore, first-year students think they are competent by claiming it is something they have already worked on previously, ignoring the fact that the minimum level of development for this dimension will not be reached if they do not have specific training during the programme.

D4. Personal and professional aspects:

First-year students are not accurate in self-assessing this dimension. They perceive themselves as highly competent, while fourth-year students fail in the assessment of this dimension. Only second-year students who are given specific training fulfil the minimum score established for this dimension (70%). Therefore, we believe that the training programmes that aim to develop TDC should work intensively on personal and professional aspects assessed in D4, particularly during the in-service training at schools (Instefjord & Munthe, 2017).

Previous studies carried out in Spain obtained similar results to those drawn from the three cases. Napal-Fraile et al. (2018) studied teacher trainees' self-assessment (in secondary education) level of digital competence. The results revealed that scores were higher in information, security and communication, and the scores were lower in content creation and problem solving (dimensions closely related to the use of DT to transform the teaching-learning processes). These authors point out the need to focus on the relational and pedagogical aspects of the integration of digital technologies in education.

To sum up, our proposal aims to enable pre-service teachers not only with tools for (self-)assessment and certification, but also, and more importantly, it highlights the main aspects in training processes to develop TDC. The proposal explained in case 2 aims to set up the development of the pre-service teachers' digital competence, through continuous/formative assessment. This is a key factor for their future professional practices as in-service teachers. Therefore, it is fundamental to make first-year students

conscious of their misconception about self-assessment and not underestimate training as a key learning process.

A proposal for pre-service TDC training

The need to incorporate TDC into pre-service teacher training programmes has emerged from findings in the three cases studied. Even so, evidence from research reveals that teacher training focused on the use of technology is still not enough (Fernandez-Batanero et al., 2020). The results for each TDC dimension were presented and discussed in the three cases. In particular, case 2, in which students had specific training, provides some interesting clues about how to set up pre-service teacher training processes for developing TDC. These outcomes helped us define two training programmes. On one hand, a general training programme that is taught at the University, and on the other hand, a specific programme that is implemented jointly by the University and schools. It also helped us design continuous and standardised assessment procedures.

Figure 1. TDC training scheme for future teachers

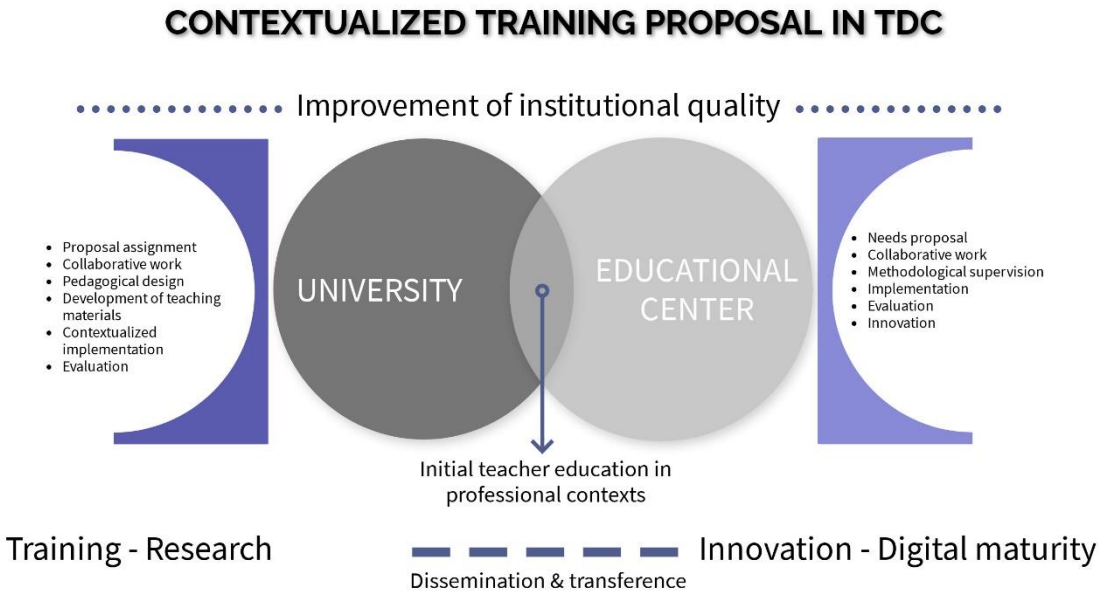

Figure 1 shows how, as institutions responsible for training teachers, universities should provide programmes to empower pre-service teachers with the necessary tools for them to become highly qualified professionals who work hand in hand with the upcoming evolution of technological advances (European Commission, 2018a & b). Based on this

and the results of the three cases studied, we believe that it is a fundamental strategy to combine higher educational programmes with in-service teacher training in real educational and institutional contexts in order to ensure the quality of pre-service teacher training (COM, 2018).

While universities provide a combined training programme in professional contexts, which focuses largely on developing competences such as TDC, schools cover other needs. Schools' resources are based on giving personalized digital teaching materials produced in collaboration with pre-service teachers, who at the same time reuse this materials for their own in-service practices. Trained teachers already working at these institutions play a guiding role for pre-service teachers and provide them with feedbacks during the development of classroom sessions. All these pedagogical framework reinforce TDC pre-service development in dimensions 1 (teaching, curricular and methodological aspects) and 4 (professional development), which are the dimensions that need to be emphasised, as highlighted by our study results.

Beyond training, this proposal also aims to enable universities to carry out applied research in professional contexts with schools. This will not only benefit schools with good results coming from innovative processes, but also increase their reputation as institutions working with universities. In short, the results of these processes can be transferred directly to the initial pre-service teacher training to enrich the curricula of higher education programmes.

Conclusions and future lines of research

There are still some different perspectives among the standard conception of how professional competences in general, and TDC in particular are measured and the possible ways in which this standardisation can be implemented. The issues that still need to be addressed are: 1) whether the period in which the TDC qualification is fixed or flexible, and 2) whether the assessment is based on knowledge or competence (Lang et al., 2015). The analysis of these two issues will enable us to understand certification in Catalan Higher Education as the next step to be taken after specific TDC training is implemented.

The three cases discussed in this paper make it clear that there is an undeniable need for TDC training that involves both higher education and schools working hand in hand in the formative assessment of this competence. Without acknowledging this

training and assessment, first-year pre-service teachers will underestimate and falsely perceive the TDC development level required to become an adequate and qualified in-service professional as established by the Catalan Government.

The Catalan higher education system does not have enough resources at its disposal to consider a certification process with both standardised and qualitative assessment tools. Therefore, researchers must continue working on two fundamental lines. The first line should focus on retrieving qualitative data in order to complement the quantitative data already collected. This would allow researchers to make the training and assessment proposed in this paper more widely applicable. The second line is to incorporate this training in TDC into the curricula of the bachelor's degree programmes, which would guarantee pre-service teachers' approval of a standardised summative assessment test to certify them in Teacher Digital Competence.

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- XXXXXXXXXXXXXX Ref. xxxxxxxxxxxx

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