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What do we know about 21st Century Skills, Technologies and Initial Teachers Training? A Scoping Literature Review

Alexandra Loução
UIDEF - Unidade de Investigação e Desenvolvimento em Educação e Formação da Universidade de Lisboa, Portugal
mariaalexandraloucao@edu.ulisboa.pt
ORCID: https://orcid.org/0000-0003-3593-7576

Ana Pedro
Instituto de Educação da Universidade de Lisboa, Portugal
aipedro@ie.ulisboa.pt
ORCID: https://orcid.org/0000-0001-7434-0321

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Abstract
Twenty first century skills and digital technologies have become more relevant in educational sciences, with a greater emphasis on school education, but also in teachers training. Several studies highlight its relevance to Initial Teachers Training, but also some vulnerabilities. This study aims to identify the research main trends between 2000 and 2020 on the development of competencies and the integration of digital technologies in initial teachers training. A five-stage Literature Review was conducted, based on document selection and data charting to examine the scope and nature of the most relevant studies. This methodology results in 998 references that integrate the three dimensions analyzed, whereby the dimension of competencies stood out the most with 39.67% of the references, followed by Initial Teacher Training with 31.40% and technology with 28.94%. The results reveal what are the current needs of elementary school teachers regarding the development of competencies, the strengths and vulnerabilities of initial teachers training and the enabling and conditioning factors for the integration of technologies in training.

Keywords: 21st Century Skills; Technologies; Initial Teacher Training; Scoping Literature Review.

[pt] O que é que sabemos sobre as competências e tecnologias do século XXI e a formação inicial de professores? Uma análise da literatura de âmbito geral

Resumo
As competências do século XXI e as tecnologias digitais têm ganho relevância na área das ciências educacionais, com maior enfâse no ensino básico e secundário, mas também na formação de professores. A investigação destaca a sua relevância na Formação Inicial de Professores, destacando algumas

fragilidades. Nesse sentido, este estudo pretende identificar as evidências na investigação realizada entre 2000 e 2020 sobre o desenvolvimento de competências e a integração das tecnologias digitais na formação inicial de professores. Utilizou-se para isso a Scoping Literature Review, que através de cinco etapas, possibilitou a seleção dos documentos e o mapeamento dos dados, por forma examinar a extensão e a natureza dos estudos mais relevantes. Do total dos documentos foi possível retirar 998 referências referentes às três dimensões analisadas, sendo a dimensão das competências a que mais se destacou com 39,67% das referências, seguida da Formação Inicial de Professores com 31,40% e, por fim, a tecnologia com 28,94%. Os resultados revelam quais as necessidades atuais dos docentes do ensino básico, no que diz respeito ao desenvolvimento de competências, as potencialidades e fragilidades da Formação Inicial de Professores e os fatores que possibilitam e/ou condicionam a integração das tecnologias nessa mesma formação.
Palavras-chave: Competências do século XXI; Tecnologias; Formação Inicial de Professores; Scoping Literature Review.

1. Purpose and background

For some time now, the concept of competence has been studied within the educational sciences, emerging as key in the training process, because of the need being evidenced when one acts effectively, using knowledge, in a problematic situation (Perrnoud, 1999). In 2006, Braslavsky, Borges, Simão, and Truong defined competence as a set of "practical and cognitive skills, knowledge—conscious or implicit—motivation, values, ethics, views, emotions and other aspects of social behavior that combine to influence an individual's decisions and actions in his professional and personal life" (p. 96).

In the last 20 years, several authors and reports have highlighted the emergence of 21st century skills (Pedro & Matos, 2019), although there is not a consensual definition among the authors: Partnership for 21st Century Skills (2002), ISTE's National Educational Technology Standards for the 21st Century Leaner (2000), NCREL's enGauge Framework (2002), AASL Standards for the 21st Century Learner (2007), National Research Council (2008), Assessment and Teaching of 21st Century Skills (2010), and others.

Digital technologies are mentioned in different frameworks and have an increasingly importance in everyone's daily life, through the proliferation of their use and also through the use on pedagogical activities during the pandemic time - COVID-19 (Batista Martins, Santos, Rufato & Brito, 2020). Nevertheless, this intensive use has not necessarily translated into knowledge and skills for a conscious and effective use (Lucas & Moreira, 2018), therefore it is still necessary to invest in education for digital and technological literacy.

It is important to promote the development of skills in Pre-service Teachers (PTs) in Initial Teacher Training (ITT) and encourage the integration of digital technologies, providing future teachers with the necessary tools for their pedagogical practice (Trilling & Fadel, 2009; Kobalia & Garakanidze, 2010; Mesquita, 2010; Pedro & Matos, 2019). However, research has revealed gaps regarding the integration of technologies in classrooms (Pedro, Piedade, Matos & Pedro, 2019; Batane & Ngwako, 2017) and in its use in ITT and particularly in the supervised pedagogical practice (Batane & Ngwako, 2017).

In addition ITT should contemplate in its curricula the enhancement of 21st century skills - i.e. critical thinking; communication; collaboration; creativity; civic and social skills; lifelong and career skills; information, media, and technology skills; digital literacy, teaching skills; and pedagogical skills - in PTs, so that they promote the development of these skills in their future students (Trilling & Fadel, 2009; Kobalia and Garakanidze, 2010; Mesquita, 2010; Pedro & Matos, 2019).

Therefore, it' s important to identify trends in the literature regarding research on ITT, in the development of PTs competencies and in the integration of digital technologies. As such, it emerges as the problem under this study, to identify the trends in the research conducted between 2000 and 2020 on the development of competencies and the integration of digital technologies in ITT.

2. Method

This study used as research methodology a Scoping Literature Review (SLR - Arksey & O'Malley, 2005). SLR consists in a literature mapping, identifying main concepts related to the topic under study, and the decision to use this research methodology was due to its relevance to the type of data to be collected and because it is an adaptable methodology to different scientific areas, since it enables the data charting to obtain key concepts in the area to be investigated (Arksey & O'Malley, 2005). Additionally, through this methodology it is possible to determine the scope of existing literature on a subject and understand its purpose (Munn, Peters, Stern, Tufanaru, McArthur & Aromataris, 2018).

The five-step framework developed by Arksey and O'Malley (2005) was followed: (1) identify and define the literature review question; (2) identify relevant studies; (3) study selection; (4) data charting; and (5) compare, synthesize and reporting results.

2.1. Identification of relevant studies

Once defined the guiding question of the study, – Which are the trends found in research conducted between 2000 and 2020 on competencies development and the integration of digital technologies in initial teacher education?) – the next step was to search and collect relevant studies, through the prior definition of descriptors and keywords (Figure 1) that helped to conduct a more focused search.

Query Ebsco

KEY AND **PUBYEAR** ("ICT"**OR** "Technology" **OR** "Digital Technology" **OR** "DigCompEdu" **OR** "TPACK" **OR** "21st century competencies" **OR** "21st century skills" **OR** "Teacher competencies" **OR** "Teacher training" **OR** "Initial teacher training" **OR** "Pre-service teachers") AND **PUBYEAR** > 2000 AND **PUBYEAR** > 2021

Figure 1. Search query for document collection

Other study inclusion criteria were scientific journal articles, dissertations/theses and books, in Portuguese, English and Spanish, with full text and free access.

2.2. Study selection

The study selection consisted in four stages - pre-selection; 1st selection; 2nd selection; and 3rd selection.

The pre-selection process consisted in reading the abstracts of the documents and gathering only the relevant documents for analysis. In the first selection of documents, a "text search" was performed using NVivo, using the keywords previously defined and a cut-off line was set regarding its frequency to exclude some of the less relevant documents.

To confirm the consistency of the data in the 257 selected documents, a "word frequency search" was performed to identify the most repeated words in those documents, and the program returned the keywords used previously.

The second selection consisted in excluding non-empirical studies and repeated documents, having been excluded 134 documents.

For the last selection, the following eligibility criteria (Table 2) were defined for documents inclusion and exclusion. As a result, 83 documents were included and proceeded to the data charting phase.

The process described below is illustrated through a flowchart in Figure 2.

Table 1.
Eligibility Criteria

	INCLUSION	**EXCLUSION**
CIENTIFIC FIELD	Initial teacher training	Lifelong Learning Continuing teacher training
TARGET GROUP	Elementary and middle school teachers	High school and university teachers

RELEVANCE	Dimensions: - teaching competencies - 21st century skills - technologies - TPACK	Dimension: - Distance education models

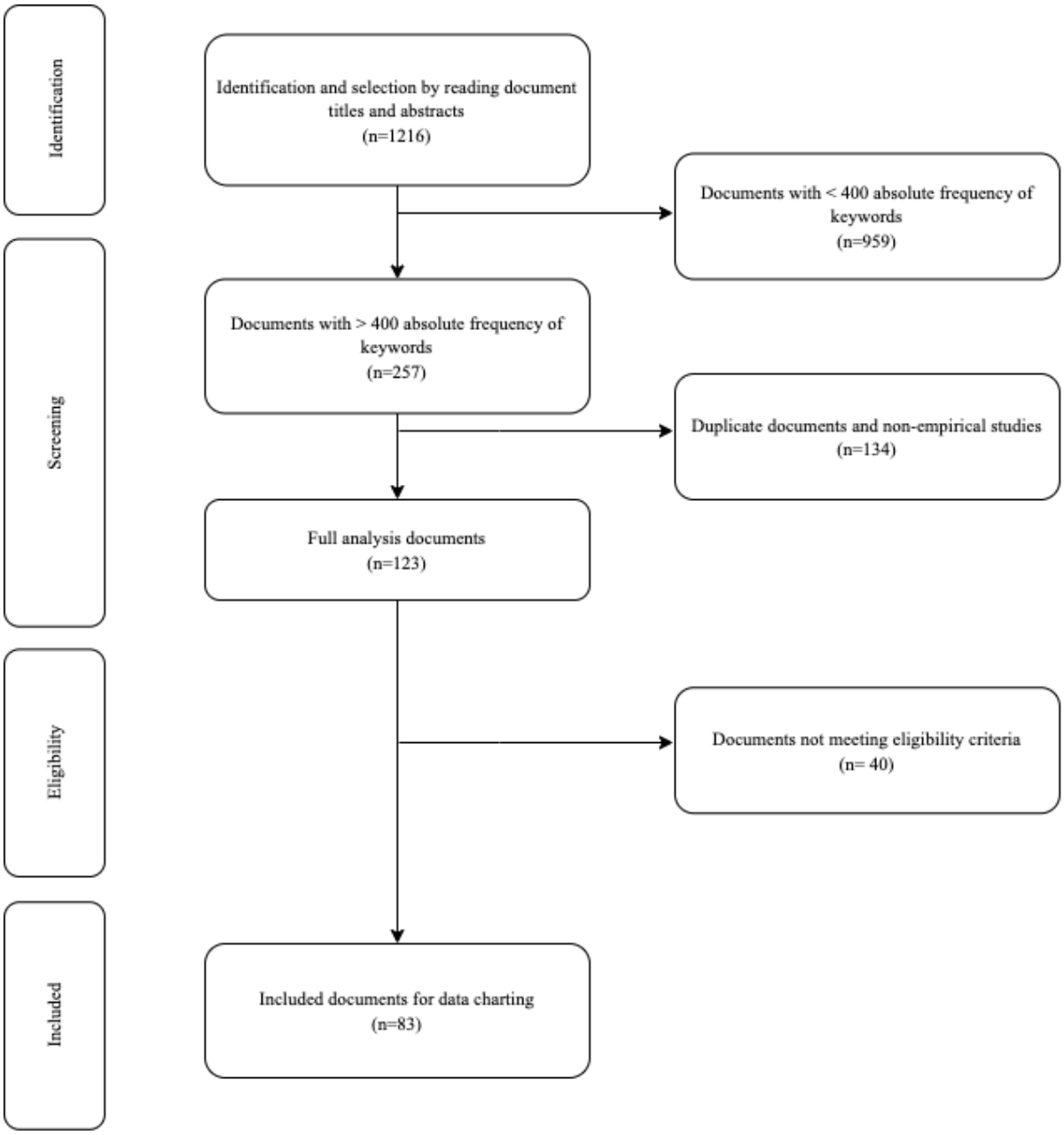

Figure 2. Flowchart of the document identification and selection process for scoping literature review analysis (Adapted from PRISMA)

2.3. Data charting

Considering the SLR objective, we proceeded with the organization, treatment and analysis of the documental corpus using three dimensions: Competencies (skills and knowledge that the teachers will need for their future teaching practice); Initial Teacher Training (organization, structure of the training

curricula, infrastructure and technological materials); and Technologies (digital tools and technological instruments).

The data collected was classified into different categories, which emerged from the dimensions defined as the most relevant themes for the study. These categories cross the various dimensions (Table 3) since they are closely related.

Table 2.
The dimensions and categories association

	CATEGORY				
DIMENSION	Profile (C1)	Factors (C2)	Perceptions (C3)	Infrastructure & Materials (C4)	Pedagogical practices & curriculum (C5)
Competencies (D1)	X	X	X		
Initial Teacher Training (D2)		X	X	X	X
Technology (D3)	X	X			

3. Results

The following figures show the percentages of items corresponding to each dimension (Figure 3) and the percentage of documents that frame each dimension (Figure 4). It is possible to verify that the values found regarding the references collected in each dimension do not show significant discrepancies (Figure 3) – Competencies (396 references), Initial Teacher Education (314 references) and Technology (288 references) – with most of the documents mentioning more than one dimension (Figure 3).

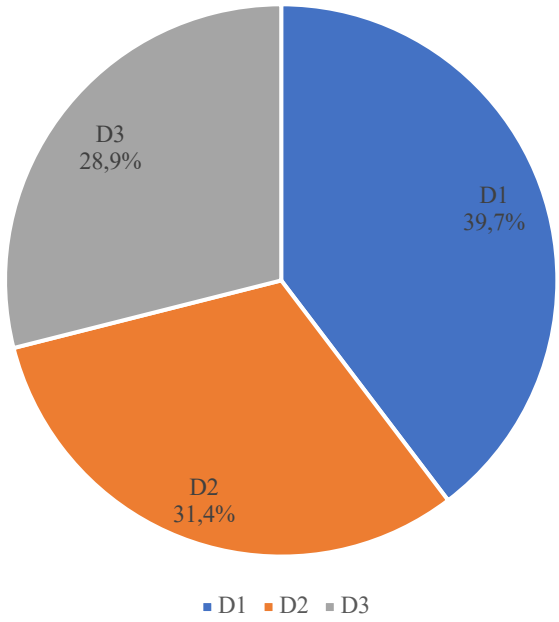

Figure 3. Percentage of items mentioning each dimension

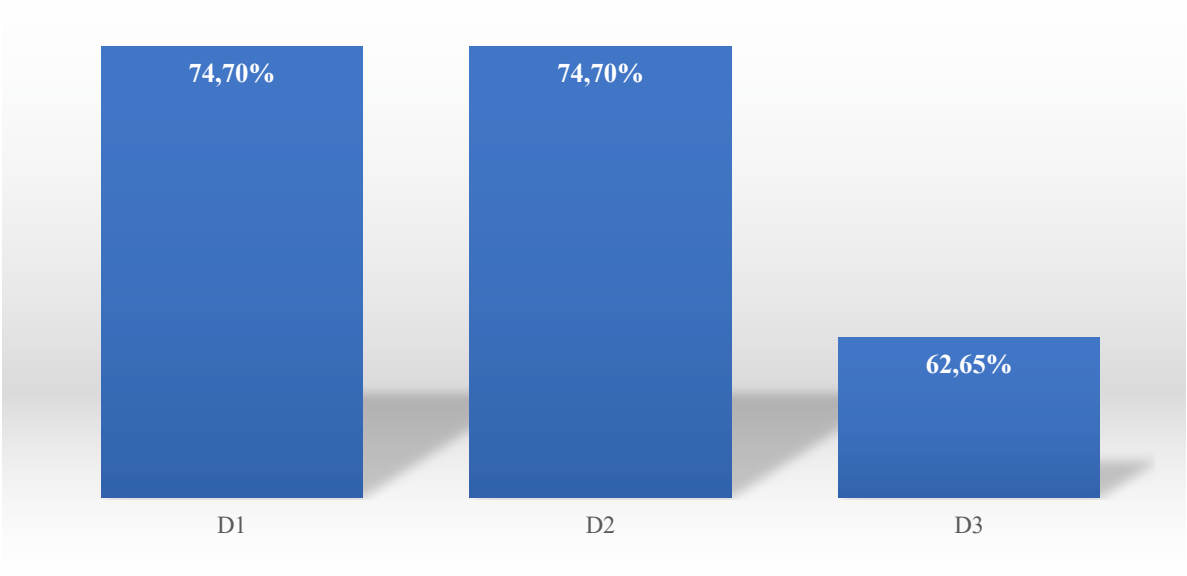

Figure 4. Percentage of documents mentioning each dimension

The Competencies dimension is represented in 62 documents and the items highlighted in these documents are divided into three categories. Table 3 shows the definitions of the different categories within this dimension, as well as the percentage of its representativity.

Table 3.
Definition and percentage of representativity of each category of dimension D1

Category	Definition	%
C1	Skills and knowledge that future teachers should acquire and develop for their future teaching practice	38,96
C2	Factors that influence the development of competencies in future teachers	41,94
C3	Future teachers' perceptions of the importance of developing competencies	19,11

As in the previous dimension, Initial Teacher Training is represented in 62 of the 83 documents reviewed, and in Table 4 we can identify the categories, its representativeness in the data set, and its' definitions.

Table 4.
Definition and percentage of representativity of each category of dimension D2

Category	Definition	%
C2	Influencing factors that influence knowledge acquisition, skills development, and technology integration in ITT	34,17
C3	ITT teachers, future teachers and stakeholders perceptions on the quality of training	18,18
C4	Infrastructure, instruments and materials at the ITT institutions	7,21
C5	Pedagogical practices and ITT curriculum	40,44

The dimension related to Technology is represented in 52 of the documents reviewed and, as in the previous dimensions, the different categories that appear in this dimension are presented in the following table (Table 5).

Table 5.
Definition and percentage of representativity of each category of dimension D3

Category	Definition	%
C1	Future teachers profile required to integrate technologies in pedagogical context	53,74
C2	Influencing factors for future teachers' integration of technologies in the classroom	46,26

4. Discussion

The data has made it possible to find the trends in research conducted between 2000 and 2020, on skills development and on the integration of digital technologies in initial teacher training. This work allowed us to identify some competencies that teachers should develop in order to carry out their professional roles (i.e. organizing and leading learning situations). However, there was no consensus in the documents reviewed on the categorization of these competencies, although there is mention of the need for PTs to develop 21st century skills (learning and teaching skills), social skills, technological and ICT skills, digital literacy and citizenship, and professional skills.

Nevertheless, studies point out the lack of PTs preparation in competencies and TPACK development (Technological, Pedagogical and Content Knowledge), although both were mainly associated with the integration and use of technologies in classroom (Cekić-Jovanović, Stepić & Miletić, 2020; McGarr & McDonagh, 2020; Urbani, Roshandel, Michaels & Truesdell, 2017; Valtonen, Kukkonen, Kontkanen, Mäkitalo-Siegl, Sointu, 2018).

Supporting the lack of PTs preparation, this review also highlighted the low self-confidence felt by prospective teachers regarding their skills and knowledge, a fact that ultimately hampers their professional performance (Al-Abdullatif, 2019; Tondeur, Aesaert, Prestridge & Consuegra, 2018; Valli, Perkkilä & Valli, 2014).

The data find consistency in those presented by Koh, Woo, and Lim (2013), referring the need for teaching methodologies to be student-centred, with the pedagogical intention of developing 21st century skills (Valli et al., 2014) in ITT, as both will favor PTs pedagogical practices (Bedir, 2019).

Moreover, Fonseca (2019) mentions that ITT teachers are insecure about ICT and, for this reason, there is use resistance and that is often a result of a lack of technologies training.

The fact that the institutions that train PTs do not have structured courses prepared for ICTs integration and competencies development is also a conditioning factor for their training (Agyei & Voogt, 2011; Göksün & Kurt, 2017), as well as the lack of infrastructure and materials, which are often non-existent or limited in number (Tran, Phan, Le & Nguyen, 2020).

PTs believe that the competencies are essential to their future profession for two reasons: (1) to be able to develop them in their future students; (2) to integrate technologies into the classroom (Wünsch, 2013). Still, PTs consider their training to be sparse and inadequate, regarding to developing those competencies and knowledge that will enable them to integrate technologies in classroom (Alev, 2003; Alsharief, 2018; Brun & Hinostroza, 2014; Cuhadar, 2018; Gudmundsdottir & Hatlevik, 2018; Kopish & Marques, 2020; Masoumi, 2020).

There is a lack of guidelines in ITT curricula for the development of 21st century skills and use of digital technologies (Nakamoto & Carvalho, 2020), so it is essential to reconfigure ITT, starting by integrating technology in teaching practices and in training curricula, systemically and systematically, so that PTs understand its importance and how they may be useful in the future (Al-Abdullatif, 2019; Aslan & Zhu, 2016, 2017; Fonseca, 2019; Nakamoto & Carvalho, 2020; Tondeur, Scherer, Siddiq & Baran, 2017; Tondeur et al. , 2018).

The representation of the promotion of these competencies in the ITT curricula is very low. The data showed that, in the curricula, there is a very low reference to the promotion of several competencies,

like Metacognition, Creativity and Innovation, Leadership, Productivity and Accountability, Problem Solving and Collaboration. These results will be developed in another article.

In this respect, the TPACK Framework will help reconfiguring ITT programs and evaluating PTs (Chai, Koh, Tsai & Tan, 2011).

The ITT courses changes must be combined with pedagogical and didactic knowledge so that PT's develop competencies and use technologies consciously rather than a merely daily use (Cekić-Jovanović et al., 2020; Yurdakul, 2018).

Moreover, ICT should not be part of a single course unit disconnected from the others but should be integrated into each of the other course units (Haydn, 2014; Valtonen, Sointu, Kukkonen, Häkkinen, Järvelä, Ahonen, Näykki, Pöysä-Tarhonen & Mäkitalo-Siegl, 2017).

In conclusion, we were able to identify a set of competencies that future teachers should develop, which are their training needs and factors that influence their competence development and integration of technologies in the classroom.

5. Conclusions

The analysis conducted provided some conclusions about 21st century skills and the integration of digital technologies in ITT.

The literature reveals that there is a wide range of conceptual definitions about the 21st century skills that PTs should develop to carry out their teaching practice, however, it was possible to gather a set of common and non-common competencies, highlighting the presence of technologies as a common and essential element.

The PTs' perceptions are consistent with the literature as they see the development of 21st century skills as important for their teaching practice, yet they have low self-confidence.

Regarding ITT, teachers are still resistant to integrating technologies, and this is due to their insecurity, as they also lack specific training in the use of these tools. In addition, there is still a need to reformulate ITT courses and curricular units so that teachers can train PTs through competence development, also integrating technologies.

Therefore, the ITT has an important role in promoting the use of technologies by PTs, providing positive experiences that will turn into positive attitudes.

To integrate technologies in the classroom it is not enough to know technological tools, it is necessary that the PTs have an adequate profile that includes some of the 21st century skills, self-confidence and positive attitude.

As research prospective it would be important to conduct an analysis of teacher training curricula, focusing on the presence of objectives that promote these competencies and in the integration of digital technologies. It also will be important to understand from the stakeholders - students and teachers in higher education - what their perspectives are on the importance of developing these competencies and whether they consider that they are developed throughout training.

References

Agyei, D. D. & Voogt, J. (2011). ICT use in the teaching of mathematics: Implications for professional development of pre-service teachers in Ghana. *Education and Information Technologies, 16*(4), 423-439. https://doi.org/10.1007/s10639-010-9141-9

Al-Abdullatif, A. M. (2019). Auditing the TPACK Confidence of Pre-Service Teachers: The Case of Saudi Arabia. *Education and Information Technologies*, *24*(6), 3393-3413. https://doi.org/10.1007/s10639-019-09924-0

Alev, N. (2003). *Integrating Information and Communications Technology (ICT) into Pre-Service Science Teacher Education: The Challenge of Change in a Turkish Faculty of Education* (Tese de Doutoramento, University of Leicester, Leicester, United Kingdom).

Alsharief, T. (2018). *Pre-Service Teachers' Perceptions of the Barriers to ICT Integration in their Future Instructional Practice in a Gulf State* (Tese de Doutoramento, University of Liverpool, Liverpool, United Kingdom). https://doi.org/10.17638/03026617

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological Framework. *International Journal of Social Research Methodology, 8*(1), 19-32. https://doi.org/10.1080/1364557032000119616

Aslan, A. & Zhu, C. (2016). Influencing factors and integration of ICT into teaching practices of pre-service and starting teachers. *International Journal of Research in Education and Science (IJRES), 2*(2), 359-370. https://doi.org/10.21890/ijres.81048

Aslan, A. & Zhu, C. (2017). Investigating variables predicting Turkish pre-service teachers' integration of ICT into teaching practices. *British Journal of Educational Technology, 48*(2), 552-570. https://doi.org/10.1111/bjet.12437

Batane, T. & Ngwako, A. (2017). Technology use by pre-service teachers during teaching practice: are new teachers embracing technology right away in their first teaching experience?. *Australasian Journal of Educational Technology, 33*(1), 48-61. https://doi.org/10.14742/ajet.2299

Batista Martins, S. C., Santos, G. ., Rufato, J. A. ., & Brito , G. S. . (2020). As Tecnologias na Educação em Tempos de Pandemia : Uma Discussão (Im)pertinente. *Interacções, 16*(55),

Bedir, H. (2019). Developing a framework for the integration of 21st century learning and innovation skills into pre-service ELT teachers' practicum. *International Online Journal of Education and Teaching (IOJET), 6*(4), 828-843.

Braslavsky, C.; Borges, C.; Simão, M.; Truong, N. (2006). Historical Competence as a Key to Promote Democracy. In: IBE/UNESCO. School Knowledge in Comparative and Historical Perspective: Changing Curricula in Primary and Secondary Education. Geneva: IBE/UNESCO.

Brun, M., & Hinostroza, J. E. (2014). Learning to become a teacher in the 21st century: ICT integration in Initial Teacher Education in Chile. *Educational Technology & Society, 17* (3), 222–238.

Cekić-Jovanović, O., Stepić, G. & Miletić, A. (2020). Future Preschool Teachers' Atitudes about 21st-Century Digital Skills. *Journal Plus Education, 27*(2), 276-303. https://doi.org/10.24250/JPE/2/2020/OJ/GS/AM

Chai, C. S., Koh, J. H. L., Tsai, C. & Tan, L. L. W. (2011). Modeling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education, 57*, 1184-1193. https://doi.org/10.1016/j.compedu.2011.01.007

Cuhadar, C. (2018). Investigation of Pre-service Teachers' Levels of Readiness to Technology Integration in Education. *Contemporary Educational Technology, 9*(1), 61-75. https://doi.org/10.30935/cedtech/6211

Fonseca, M. G. (2019). As Tecnologias de Informação e Comunicação na Formação Inicial de Professores do 1º Ciclo do Ensino Básico – Fatores Constrangedores Invocados pelos Formadores para o Uso das Tecnologias. *Educação & Formação, 4*(11), 3-23. https://doi.org/10.25053/redufor.v4i11.254

Göksün, D. O. & Kurt, A. A. (2017). The Relationship Between Pre-Service Teachers' Use of 21st Century Learner Skills and 21st Century Teacher Skills. *Education and Science, 42*(190), 107-130. https://doi.org/10.15390/EB.2017.7089

Gudmundsdottir, G. B. & Hatlevik, O. E. (2018). Newly qualified teachers' professional digital competence: implications for teacher education. *European Journal of Teacher Education, 41*(2), 214–231. https://doi.org/10.1080/02619768.2017.1416085

Haydn, T. (2014). How do you get pre-service teachers to become 'good at ICT' in their subject teaching? The views of expert practitioners, Technology. *Pedagogy and Education, 23*(4), 455-469. https://doi.org/10.1080/1475939X.2014.892898

Kobalia, K. & Garakanidze, E. (2010). The Professional Competencies of the 21st Century School Teacher. Problems of Education in the 21st century, 20, 104-108. http://www.scientiasocialis.lt/pec/files/pdf/vol20/104-108.Kobalia_Vol.20.pdf

Koh, J. H. L., Woo, H. & Lim, W. (2013). Understanding the relationship between Singapore preservice teachers' ICT course experiences and technological pedagogical content knowledge (TPACK) through ICT course evaluation. *Educational Assessment Evaluation and Accountability, 25*(4), 321-339. https://doi.org/10.1007/s11092-013-9165-y

Kopish, M. & Marques, W. (2020) Leveraging technology to promote global citizenship in teacher education in the United States and Brazil. *Research in Social Sciences and Technology, 5*(1), 45-69. https://doi.org/10.46303/ressat.05.01.3

Larson, L. C. & Miller, T. N. (2011). 21st Century Skills: Prepare Students for the Future. *Kappa Delta Pi Record, 47*(3), 121-123. https://doi.org/10.1080/00228958.2011.10516575

Lucas, M. & Moreira, A. (2018). *DigCompEdu: quadro europeu de competência digital para educadores*. Aveiro: Universidade de Aveiro.

Masoumi, D. (2020). Situating ICT in early childhood teacher education. *Education and Information Technologies, 26*(1). https://doi.org/10.1007/s10639-020-10399-7

McGarr, O. & McDonagh, A. (2020). Exploring the digital competence of pre-service teachers on entry onto an initial teacher education programme in Ireland. *Irish Educational Studies, 40*(3), 1-14. https://doi.org/10.1080/03323315.2020.1800501

Mesquita, E. C. (2010). Formação inicial, profissão docente e competências para a docência: a visão dos futuros professores. *Revista de Educação, 2*(1), 3-19. https://doi.org/10.34620/eduser.v2i1.15

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A. & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*, 1-7. https://doi.org/10.1186/s12874-018-0611-x

Nakamoto, P. & Carvalho, A. A. (2020). Digital technologies in initial teacher education: a study in the masters in teaching at the University of Coimbra, Portugal. *Research, Society and Development, 9*(7), 1-25. https://doi.org/10.33448/rsd-v9i7.4587

Pedro, A. Matos, J. (2019). Competências dos Professores para o Século XXI: uma abordagem metodológica mista de investigação. e-Curriculum, 17(2), 344-364. https://doi.org/10.23925/1809-3876.2019v17i2p344-364

Pedro, A., Piedade, J., Matos, J. F. & Pedro, N. (2019). Redesigning initial teacher's education practices with learning scenarios. *The International Journal of Information and Learning Technology, 36*(3), 266-283. https://doi.org/10.1108/IJILT-11-2018-0131

Perrenoud, P. & Magne, B. C. (1999). Construir as competências desde a escola. Artmed.

Tondeur, J., Aesaert, K., Prestridge, S. & Consuegra, E. (2018). A multilevel analysis of what matters in the training of pre-service teacher's ICT competencies. *Computers & Education, 122*, 32-42. https://doi.org/10.1016/j.compedu.2018.03.002

Tondeur, J., Scherer, R., Siddiq, F. & Baran, E. (2017). A comprehensive investigation of TPACK within pre-service teachers' ICT profiles: Mind the gap!. *Australasian Journal of Educational Technology, 33*(3), 46-60. https://doi.org/10.14742/ajet.3504

Tran, T., Phan, H. A., Le, H. V. & Nguyen, H. T. (2020). ICT Integration in Developing Competence for PreService Mathematics Teachers: A Case Study from Six Universities in Vietnam. *International Journal of Emerging Technologies in Learning (iJET), 15*(14), 19-34. https://doi.org/10.3991/ijet.v15i14.14015

Trilling, B. & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. San Francisco: Jossey-Bass

Urbani, J. M., Roshandel, S., Michaels, R. & Truesdell, E. (2017). Developing and Modeling 21st-Century Skills with Preservice Teachers. *Teacher Education Quarterly, 44*(4), 27-50. https://eric.ed.gov/?id=EJ1157317

Valli, P., Perkkilä, P., & Valli, R. (2014). Adult pre-service teachers applying 21st century skills in th practice. *Athens Journal of Education, 1*(2), 115-129. http://www.atiner.gr/journals/education/2014-1-2-2-Valli.pdf

Valtonen, T., Kukkonen, J., Kontkanen, S., Mäkitalo-Siegl, K. & Sointu, E. (2018). Differences in pre-service teachers' knowledge and readiness to use ICT in education. *Journal of Computer Assisted Learning, 34*(2), 174-182. https://doi.org/10.1111/jcal.12225

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. *Australasian Journal of Educational Technology, 33*(3). https://doi.org/10.14742/ajet.3518

Wünsch, L. P. (2013). *Formação Inicial de Professores do Ensino Básico e Secundário: Integração das Tecnologias da Informação e Comunicação nos Mestrados em Ensino* (Tese de Doutoramento, Universidade de Lisboa, Lisboa, Portugal).

Yurdakul, I. K. (2018). Modeling the relationship between pre-service teachers' TPACK and digital nativity. *Educational Technology, Research and Development, 66*(2), 267-281. https://doi.org/10.1007/s11423-017-9546-x

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Contribucción de autores

Author 1 – Conceptualization, methodology and results.
Author 2 – Writing, review and editing.
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