Migration Letters

Volume: 20, No: 12 (2023), pp. 870-885

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Digital Technologies As A Medium Or Mediation: A Review From Pedagogical Content Knowledge

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Abstract

The COVID-19 pandemic forced participants in traditional educational systems to interact in a "digitally mediated face-to-face" manner. This research aims to review reports in Spanish, English, and Portuguese published in indexed journals in recognized databases over the last six years that account for incorporating digital technologies as a medium or mediation. The research is bibliographic, using the bibliographic information mapping method. The "a priori" categories correspond to Pedagogical Content Knowledge. Using the search engines of the databases, documents that met the criteria were selected: documents published in the last six years, incorporating technology or natural sciences (physics, chemistry, biology, or mathematics) at any educational level, and written in Spanish, English, or Portuguese.

In the initial search, we found 247 documents. After reviewing their relevance to the research objective, we identified 69 articles (31 in Spanish, 12 in Portuguese, and 26 in English) that met the search criteria. We classified these articles and selected 5 of them for a meta-analysis. In conclusion, we identify that teacher trainees should consider digital technologies throughout their training process to transition from being a medium to becoming mediation.

Keywords: *Digital technologies as mediation, study of natural sciences, pedagogical content knowledge.*

Introduction

In various dimensions of society, Digital Technologies (DT) create scenarios for interaction among people (Tabares-Quiroz & Correa-Vélez, 2014). Due to the COVID-19 pandemic, worldwide educational systems, traditionally conducted in person, were compelled to resort to technology-mediated education, thus configuri[1]ng an experiment in which certain web-based digital technologies served as a means for interactions. In this scenario, educators face the challenge of continuing teaching activities by utilizing digital technologies as a medium or mediation in the formative processes.

In a comprehensive analysis, Gros et al. (2020) point out that the presence of DT does not imply educational innovation; indeed, traditional teaching is not affected by the presence and use of DT. Similarly, the widespread presence of hardware and software only sometimes transforms teaching activities. However, there is evidence indicating that in educational innovations, it is possible to consider DT (Area & Adell, 2021; Artun et al., 2020; Camargo-Aragão & Fonseca-Diaz, 2018; García-Martínez et al., 2018).

The initial training of teachers is one of the critical focuses of dedication and demand in academic communities, particularly in the field of education, as they will be the ones inspiring

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the transformation and inclusion of DT in the educational process. In-service teachers exhibit excellent attitudes and motivation for incorporating DT; however, their training in the use of DT and the didactic aspects of their integration into the classroom is fundamental (Cabero-Almenara & Martínez-Gimeno, 2019).

Teacher training is increasingly becoming more comprehensive (Abella-Peña & García-Martínez, 2023), considering DT as a necessary element that must be articulated and harmonized with didactic proposals for its implementation in the educational process. During the COVID-19 confinement, teachers needed to remain active, mainly using computers or mobile devices, prompting reflection on how DT can enhance contemporary learning for future teachers (Rodríguez-Zidan et al., 2019).

In both the context of initial teacher training and practicing teachers, the research and this article guide the question: How have teachers employed digital technologies from the perspective of didactic content knowledge, based on research reports published in indexed journals in the last six years, in incorporating digital technologies in the field of education as a means or mediation?

Theoretical frame

The necessary knowledge for teacher training or that supports the teaching profession, initially proposed by Shulman (1986, 1987), revolves around making disciplinary content teachable to others, expanding the initial perspective that focused on academic performance. Shulman (1987) suggests elements inherent to teaching, including knowledge of student understandings, context, curriculum, teaching strategies, assessment of learning, general pedagogical knowledge, and knowledge of educational goals, purposes, values, and their philosophical and historical foundations.

Similarly, Digital Technologies (DT) currently provide a range of services and possibilities as a means for interactions in the field of education. Teachers are responsible for studying and reflecting on them to understand how to incorporate them into teaching activities.

In education, especially in teaching, educators can view digital technologies (DT) as integral components of the means, materials, and opportunities within educational environments. These technologies can play a role in configuring mediation scenarios between the act of learning and the students. Educators consider DT a mediation for learning when they place it within a specific educational context with a defined purpose (Impedovo et al., 2015; Suárez, 2014). In this context, DT serves as mediation artifacts with diverse interpretations influenced by the surrounding context and intended purpose.

Methodology

The research is bibliographic with a qualitative approach (Gómez, 2009; McMillan & Schumacher, 2005). The technique used is bibliographic informational mapping (Molina et al., 2012). For information processing, a spreadsheet and qualitative analysis software are employed.

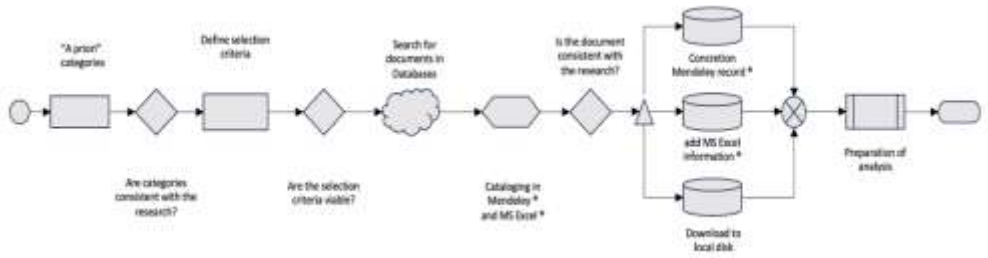

Figure 1. The process followed in the execution of the study was as follows:

The research process consists of four phases: In Phase 1, we configure the project.; Phase 2, "information gathering," using database search engines (Scopus, Google Scholar, Scielo) to identify online publications from 2018 to 2023; Phase 3, "Information Processing," downloading information, creating a spreadsheet with study subcategories, categorizing each article, selecting articles according to the research question and objective, and finally categorizing and documenting; Phase 4 "creation," proceeding to write research reports.

The instrument used is a spreadsheet with subcategories derived from the categories:

Pedagogical Content Knowledge (as proposed by Shulman (1987))

Use of Digital Technologies (as a medium and mediation)

the disciplinary connection of the study (Physics, Chemistry, Biology, and Mathematics)

educational level (Basic, Middle, and Higher)

language (English, Portuguese, and Spanish)

Results and Discussion

This section is organized based on the "a priori" variables and a construction derived from the inferences that emerge from the study. The articles included in the study are written in Spanish (31), English (26), or Portuguese (12). The years covered were 2018 (6), 2019 (11), 2020 (12), 2021 (11), 2022 (20), and 2023 (9). The significant increase in publications in 2022 may be attributed to the COVID-19 pandemic, as more than 12 publications are related to this event.

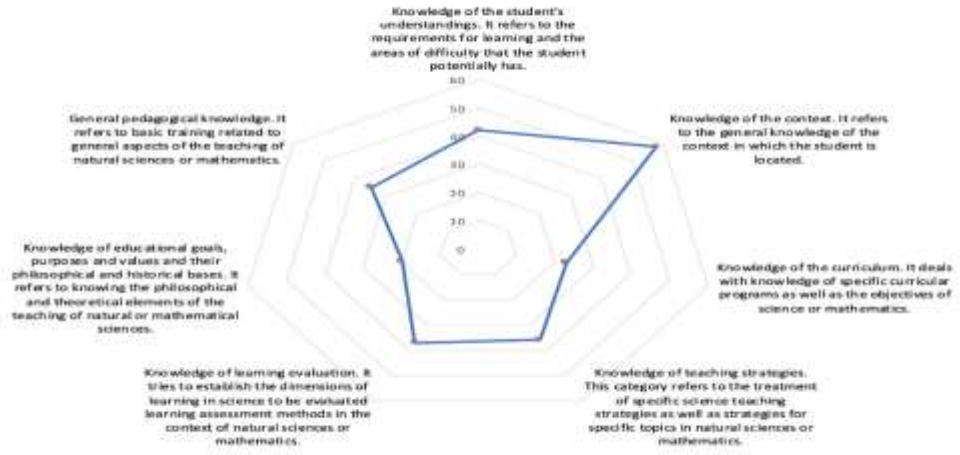

Figure 2. Distribution of the Recurrence of Articles by Subcategory of Pedagogical Content Knowledge.

Figure 2 represents the number of articles categorized in each of the seven categories proposed by Shulman (1987). Educators in science or mathematics typically prioritize teaching tasks that involve knowledge of the context in which students find themselves and understanding of the student. These are the subcategories with the highest recurrence. In a secondary position, there is knowledge of teaching strategies, learning assessment, and general pedagogical knowledge. In third place is knowledge of the curriculum, the aims, purposes, and educational values, along with their philosophical and historical foundations, which reveals three trends in the academic focus of academic communities.

A. Aspects of Teaching Sciences or Mathematics with Students:

Educators revisit the transformation of teaching based on knowledge and explore the possibilities of competency-based teaching to enhance student understanding and motivation. This exploration draws on various pedagogical models and approaches. In this context, technologies such as virtual labs or simulations can either facilitate or hinder the actions of educators (Abumalloh et al., 2021; Afacan-Adanır et al., 2022; Alegre-Buj & Cuetos-Revuelta, 2020; Alves et al., 2023; Area & Adell, 2021; Artun et al., 2020; Barbosa, 2021; Cabello et al., 2020; Camargo-Aragão & Fonseca-Diaz, 2018; Cerda et al., 2018; Christopoulos et al., 2023; De-Quadros et al., 2018; Diwakar et al., 2023; Donkin et al., 2019; Dos Santos-Leal & Aparecido-De Oliveira, 2019; García-Martínez et al., 2018; Gomes-, 2022; Guaita & Gonçalves-Peres, 2022; Marcos-Merino, 2019; Martínez-Arguello et al., 2018; May et al., 2022; Pérez-Higuera et al., 2020; Regner et al., 2022; Rizzatti & Prestes-Jacaúna, 2022; Salmerón & Delgado, 2019; Sánchez-Caballé & Esteve-Mon, 2023; Santos-Braga et al., 2019; Sari et al., 2019; Sasmito & Sekarsari, 2022; Shehada et al., 2020; Singh et al., 2020; Suyanta et al., 2022; Vela-Acero & Jiménez-Cortés, 2022; Velaora et al., 2022; Velasco, 2020; Wong et al., 2023; Xavier et al., 2019).

B. Understanding Teaching Strategies - Evaluation - Pedagogy in General:

This knowledge involves harmonizing aspects of pedagogy, didactics, and technology with subject-specific knowledge in sciences or mathematics for teaching. Research focused on educators' forms of teaching and learning with digital technologies is identified as contributing to curriculum transformation. This could help alleviate limited utilization of the wealth of hardware and software in education, potentially impacting student outcomes in various assessments and overall educational aspects (Abella-Peña & García-Martínez, 2023; Afacan-Adanır et al., 2022; Alegre-Buj & Cuetos-Revuelta, 2020; Artun et al., 2020; Cerda-González et al., 2022; Christopoulos et al., 2023; De-Quadros et al., 2018; De Souza et al., 2021; Diwakar et al., 2023; Donkin et al., 2019; Dos Santos-Leal & Aparecido-De Oliveira, 2019; García-Martínez et al., 2018; Gomes-, 2022; Guaita & Gonçalves-Peres, 2022; Hidalgo-Cajo & Gisbert-Cervera, 2021; Jimenez-Sánchez et al., 2022; Marcos-Merino, 2019; Martínez-Arguello et al., 2018; May et al., 2022; Nova-Nova et al., 2022; Paz-Saavedra et al., 2022; Pérez-Higuera et al., 2020; Rizzatti & Prestes-Jacaúna, 2022; Sari et al., 2019; Sasmito & Sekarsari, 2022; Sezgin & Sevim-Cirak, 2021; Singh et al., 2020; Suyanta et al., 2022; Vela-Acero & Jiménez-Cortés, 2022; Wong et al., 2023; Zorrilla & Mazzitelli, 2021).

C. Broader Aspects of Education and Curriculum:

Digital technologies permeate contemporary society; in the educational realm, promoting technical training for educators in using digital technologies and curriculum planning for their integration can have at least two consequences. Firstly, it can bring about positive changes in educators' emotions and confidence in using technology in the classroom, and secondly, it can incorporate digital technologies into educational purposes. Additionally, for individuals with

physical or cognitive differences, the incorporation of digital technologies by educators contributes to increased autonomy for this student population (Alegre-Buj & Cuetos-Revuelta, 2020; Area & Adell, 2021; Barbosa, 2021; Cabello et al., 2020; De-Quadros et al., 2018; De Souza et al., 2021; Díaz-Barriga, 2021; Diwakar et al., 2023; Donkin et al., 2019; Guaita & Gonçalves-Peres, 2022; May et al., 2022; Regner et al., 2022; Sari et al., 2019; Sasmito & Sekarsari, 2022; Sezgin & Sevim-Cirak, 2021; Shehada et al., 2020; Singh et al., 2020; Vela-Acero & Jiménez-Cortés, 2022; Xavier et al., 2019; Zúñiga-Meléndez et al., 2020).

Digital Technologies as a Medium

The recent COVID-19 pandemic brought digital technologies to the forefront as a crucial element that mitigated its impact across various dimensions of human life, particularly within the educational system. The pandemic highlighted and exacerbated social inequalities in education (Coppi et al., 2022), underscoring the need for digital literacy (Graça et al., 2023). Digital technologies serve as a means to facilitate interaction among stakeholders of the educational system, possibly helping to alleviate the impact on mental and physical health (Bodoque-Puerta et al., 2022).

In educational systems, the presence of digital technologies mitigated the crisis caused by the COVID-19 pandemic (Díaz-Barriga, 2021). Simultaneously, it raised concerns about the need to transform teaching and, more broadly, the school system to instigate an evolution of educational systems (Núñez-Naranjo & Chancusig-Toapanta, 2022). However, despite their contribution to maintaining remote learning during the pandemic, digital technologies did not significantly influence the transformation of educational practices (May et al., 2022).

In light of the above, digital technologies have been consolidating as a set of tools or resources that enhance interaction possibilities among stakeholders across various environments and levels of educational systems. They have become a means of establishing one-to-one, one-to-many, many-to-many communication, or perhaps serving as a medium for storage and transmission, among various services—essentially functioning as a "tool for."

Digital Technologies as Mediation

Experimentation is a fundamental part of the epistemology of science. In science education, the didactics of science transpose scientific experiments into experimental activities in teaching science, serving as an immersive activity in scientific culture. Laboratory activities in education, therefore, act as mediators in the teaching and learning of science. The intention behind such mediation can vary, from replicating well-known experiments with expected outcomes to exploring phenomena where the goal is to construct ideas with uncertain results.

The integration of digital technologies as an integral part of scientific experiments has been occurring for several decades. In specific approaches and cases, theoretical physics relies on calculations or simulations. In physics education, mobile devices, computer interfaces with sensors, and computer or web-based simulations, among other means, have been incorporated to enhance experimental activities in what is known as virtual laboratories.

In physics education, educators have integrated mobile devices, computer interfaces with sensors, and computer or web-based simulations, among other means, to enhance experimental activities in what is known as virtual laboratories. This integration represents a transposition of mediation inherent in scientific activity, providing students with new experiences that seemingly increase motivation (Sari et al., 2019; Velaora et al., 2022).

In biology education, virtual reality devices (360° stereoscopic) facilitate learning and allow interaction with the subject of study. This interaction, with visualization characteristics, induces cognitive representations in students, thus acting as instrumental and cognitive mediation for learning sciences.

In chemistry education, we identified challenges in incorporating digital technologies with the potential to build molecules, analyze concentrations, or study states of matter. These challenges are often directly associated with teachers (Xavier et al., 2019), whose technology primarily focuses on videos, articles, and PowerPoint® presentations (Martínez-Arguello et al., 2018). However, other studies show proper use promotes student understanding and motivation (Diwakar et al., 2023; Sasmito & Sekarsari, 2022). Virtual laboratories, particularly in biology and chemistry, appear to mitigate risks associated with using biological or chemical materials that may pose a danger to humans without proper handling (Peres-Gonçalves et al., 2019).

Integration of Digital Technologies: Self-regulation and Didactic Transposition

In integrating Digital Technologies (TD), self-regulation has emerged as a crucial element, as articulated by Zimmerman (1990). Self-regulation is associated with consciously planned, controlled, managed, and monitored emotions and actions. Within the reviewed publications, various facets of self-regulation have been identified, including motivation (Afacan-Adanır et al., 2022; Diwakar et al., 2023; Lahmidi et al., 2019; Sari et al., 2019; Velaora et al., 2022), confidence, satisfaction, emotions (Camargo-Aragão & Fonseca-Diaz, 2018; Velaora et al., 2022), monitoring (Jimenez-Sánchez et al., 2022), and autonomy. These elements contribute to the self-regulation of both students and practicing teachers in the pursuit of developing the ability to learn, a fundamental aspect of their professional lives (Christopoulos et al., 2023).

Didactic transposition, as defined by Chevallard (1998), involves making a scientific concept teachable. Educators can engage in a bidirectional activity in which they consider mediation with TD. Videos, virtual laboratories, and other forms of TD can provide contextual elements in learning environments that enhance student education (Sasmito & Sekarsari, 2022) and broaden teaching possibilities for educators (Cerda et al., 2018).

TD has become a prevalent element in educational contexts as a medium or mediation for both pre-service and in-service teachers. As a medium, they are increasingly present in educational institutions and various social settings, particularly in urban rather than rural contexts.

However, as a mediation, there has been limited exploration. The review has shown the emergence of a scenario where TD is used to study specific topics, revealing connections with aspects such as motivation, emotions, monitoring, and, notably, self-regulation. There are also indications of a link between mediation and didactic transposition.

Conclusions

Analyzing publications related to digital technologies in indexed journals over the past six years from the pedagogical content knowledge perspective is valuable for identifying their uses, whether as a medium or mediation. This study makes the following considerations based on the presented evidence.

Limited Incorporation as Mediation: Digital technologies (TD), as a mediation tool, have been incorporated restrictively in science teaching practices. Educators predominantly focus on what to teach and to whom, with TD primarily being integrated as a means rather than a mediation tool in learning environments.

Impact of the COVID-19 Pandemic: The COVID-19 pandemic increased academic production on TD, making them a central element. However, the forced context for the presence of TD did not necessarily lead to a transformation in teaching practices or intentional incorporation of TD; they solidified as a means rather than a transformative mediation.

Need for Reflective Initial Teacher Training: Training should actively and reflectively incorporate TD across various dimensions. Developing technical proficiency in TD is crucial,

along with addressing questions about why, what for, how, when, and other critical aspects to concretize the intentional integration of TD in science and mathematics education.

Integration of Self-regulation in Teacher Training: Results highlight the need to include self-regulation in teacher training curricula and advance the relationship between self-regulation and TD.

Continuous Professional Development for In-service Teachers: Teachers may need continuous professional development programs aligned with research contexts and situated in their professional environment to integrate TD into teaching activities effectively.

Institutional Support and Infrastructure: The presence of hardware and software in educational institutions is necessary for educators to recognize TD as a medium and later incorporate them as mediation. Aligning TD with the educational project's operationalization supports community engagement.

Reflection on Contemporary Education: Advancing contemporary education involves pedagogically and didactically considering the presence of TD in diverse educational environments. Both in-service and pre-service teachers must enhance their qualifications in TD usage and deeply reflect on the implications of TD in various teaching activities.

Acknowledgments

Special recognition is extended to the Faculty of Education at the University of Nariño for their support and funding for this research. The investigation occurred within the Natural Sciences, Mathematics, and Didactics research group the University of Nariño endorsed.

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