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Digital Technology and Teacher Professional Development: Challenges and Contradictions in Compulsory Education

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Abstract: The aim of this article is to explore the role of teacher professional development (TPD) in relation to two experiences involving digital technology. Both studies were conducted at a single combined primary and secondary school and involved a total of 727 students. The first study consisted of an ex post facto analysis of attempts to improve student perception of the risks associated with inappropriate use of technology, while the second examined the possible benefits of gamified learning on mathematical fluency using a pre-test/post-test approach. The results reveal the lack of TPD in relation to both experiences, with teachers unable to overcome problems related to technology use and risk perception in the first case, and relegated to the role of mere implementers of an automated learning software product in the second. The conclusions highlight the contradiction between the image of technological innovation in schools and the reality of stasis in teaching practice, as well as the need for further research to assess and promote more effective TPD.

Keywords: teacher professional development; teachers; primary education; secondary education; digital technology; mathematical fluency; digital competence; risk behaviours

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1. Introduction

The aim of this article is to explore the role of teacher professional development (TPD) in relation to two experiences involving digital technology and educational innovation. Both studies were conducted at a single combined primary and secondary school and involved a total of 727 students. The combined analysis of digital technology and educational innovation from the perspective of TPD is designed to assess the role of the teachers involved and the improvements, if any, observed in their professional practice.

Teacher professional development is one of the most important factors in educational improvement. It involves sustained processes of formal or informal learning by teachers, undertaken individually or collectively, with the aim of mobilising the knowledge, skills, attitudes and commitments needed to bring about improvements in teaching and learning. Professional development is an ongoing process that continues throughout a teacher's career, from initial teacher training through continuing professional development and the everyday challenges of teaching practice itself. Within the current system of education, learning opportunities for teachers may be formal (courses, seminars, workshops, etc.), informal or non-formal; in-person, virtual or hybrid; individual, group-based or within professional learning communities [1–3].

1.1. Professional Development and Teacher Training

The precept of training is to promote teachers' personal and professional development throughout their professional teaching careers in a sustained process of learning from themselves, and from and with others. The conceptualisation of training as a 'system' [4] requires a clear political commitment on the part of all of the authorities involved: from

the selection and admission of candidates for teacher training [5–7]; to support for newly qualified teachers [8,9] ('in many ways the most powerful learning is just beginning as teachers enter their first classroom assignments' [4]; p. 163); and the continuing availability of supports and resources throughout their teaching careers, understood as 'an amalgam of attitudes, commitments, generosity, disposition and teacher identity, with as many variations as there are people who think, feel and teach' [1].

Continuous training is thus as essential to in-service teacher development as training for recruit and novice teachers [10,11], and should be seen as 'a journey undertaken individually and in the company of others in a rich continuum across different times and spaces' [12].

Regardless of their educational sector or level, teachers are always subject to a process of continuous professionalisation and permanent professional development. For professional development to be effective, however, it must include a systematic analysis and assessment of the relationship between teaching theory and practice, thought and action, and head and heart in the way professional knowledge is constructed. Professional development is the goal of every training action and a sine qua non of the reconstruction of teacher education [13,14]. Therefore, from the point of view of teachers as educational professionals and training as a process of socialisation, and personal and professional development, the pillars of teacher training, and the key to understanding teacher training processes and outcomes are teaching practice, continuous learning and reconstruction of professional knowledge [11].

Professional development-based teacher training places the emphasis on improving teachers' ability to deal with the uniqueness, complexity, uncertainty and conflicting values that characterise teaching practice [15], and on the role of teachers as researchers of their own practice and producers of knowledge [12,16–20]. This latter conception of teachers as researchers and creators of knowledge requires by correlation that research training be provided as part of their initiation into and development within the profession [21]. How this training process comes about depends on political, economic, institutional and personal efforts to demand and provide the resources necessary, since 'when teachers are recognised as reflexive practitioners and knowledge producers, they contribute to the growing bodies of knowledge needed to transform educational environments, policies, research and practice, within and beyond their own profession' [12] (p. 80).

Teachers should be the protagonists of their own training, not merely its recipients, for, without their personal commitment to learning, there can be no professional development or improvement in education. The corollary of this bold reconstruction of the teacher–subject (brilliantly conceptualised by Schön [15] in the figure of the reflective practitioner) and permanent professional development as the guiding principles of professional training is that teachers must be offered stimuli and incentives to adapt, change and innovate throughout their teaching careers [1,12,22,23].

1.2. Professional Development and the Irruption of Digital Technology

The conception of teacher training as a professional development process was first established in the 1970s [24,25]. This conceptual leap was founded on the assumption that teachers, like any other professional group, must attempt to keep up with the constantly shifting rules and standards of a changing world. Continuous learning, adaptation and improvement of themselves and their practice are, therefore, the right and responsibility of every teacher. In the mid-1980s, numerous articles and reports on teacher training and education highlighted the need for education policy to reflect and support teacher professional development [26–30]. Interest in the subject continued to grow throughout the 1990s, with professional development analysed as an integrated and ongoing part of educational improvement. Teachers were seen as the individuals most qualified to lead improvement of their own performance and, with it, that of their students, schools and communities [31–37].

The arrival of the 21st century witnessed the irruption of digital technology in education and the scramble to equip schools and teachers with computer devices. Since 2002, numerous (often publicly funded) studies have been conducted into the impact of information and communications technology (ICT) on the primary and secondary education systems (schools, teachers and students) in Spain and Galicia. Technology has become identified in the political, social and educational imagination as an indicator of innovation and improvement in teaching, learning, and professional and institutional development. What is less clear, however, is whether that perception is reflected in the attitudes and experience of teachers on the ground. In other words, are teachers adopting and incorporating new technology in a pedagogically critical and reflective way, or are they merely being swept up on a tide of innovation from above? TPD is the key to ensuring that teachers are equipped to manage, reflect on and propose new experiences involving digital technology.

The array of approaches, analyses and results on this topic is too extensive to review in detail here, but includes analysis and discussion of issues related to ICT innovation and teacher professional development, such as knowledge sharing, teaching cultures of collaboration, the use of ICT in innovation projects, student digital competence (DC) and the use of social media inside and outside of the classroom [38–44].

Over the past two decades, researchers, journals, and national and international organisations have been calling on politicians, governments, communities, families and schools to recognise the important work teachers do, to reconceptualise teaching as a 'collaborative profession' and to create the conditions necessary for successful professional development [1,12,45–48]. The aim: a new 'social contract' for education.

1.3. Teacher Decision-Making Regarding the Use and Impact of Digital Technology: A Case Study of TPD

To examine the challenge surrounding professional development, a number of questions must be addressed: What is the reality of TPD in schools today? What role does digital technology play in teachers' decision-making processes? Do apparently successful technological solutions serve to enhance or hinder their professional development? Are teachers equipped to deal with the challenges posed by the use of technology in the classroom?

This article reports on a case study of teacher decision-making in relation to the use and impact of digital technology as an indicator of TPD. Following Bruner's [49] suggestion that people's actions reveal what they think, feel or believe, teachers' actions and decisions are interpreted here as a reflection of their professional development, understood as the mobilisation of knowledge, skills and attitudes for the improvement of teaching and learning. The case study is based on two experiences conducted at a single school, involving the same teachers, and analyses the latter's capacity for effective, autonomous decision-making. The hypothesis explored by this analysis is the lack of coordination in schools at present between educational innovation and TPD.

The first experience relates to the development of DC among students via a specially designed programme of measures, which includes increased digitisation of teaching, integration of digital skills across the curriculum, and workshops to improve risk perception and encourage responsible use of technology. Improved self-management of digital devices is one of the core aspects of DC, since inappropriate use can lead to problems such as anxiety and depression, sleep disorders, issues around body self-perception, cyberbullying and fear of missing out (FOMO), among others [50–53]. DC is also listed among the eight 'key competences' set out by the European Framework for Lifelong Learning [54] and adopted into legislation in Spain under the 2020 LOMLOE Education Act [55]. To help promote digital learning in schools, the EU has developed a series of reference frameworks for schools and teachers, including DigComp (version 2.2) [56].

The second experience involves the acquisition and implementation of an educational software product as a way of modernising mathematical teaching at the school. The software itself is designed to improve mathematical fluency among students using 'serious games' [57], defined as 'games in which education (in its various forms) is the primary goal,

rather than entertainment' [58] (p. 17). Studies have shown that serious games can improve learning outcomes [59,60] and school curricula [61]. This study analyses the impact of a well-known mathematical fluency software programme, widely used in schools in the United States [62–64].

In both cases, teachers had the potential to improve and enrich the students' learning experience and outcomes based on their professional knowledge. The results show, however, that that potential can be impeded when teachers' capacity for deep, critical reflection is not developed: in other words, when educational innovation is not integrated into a wider ecosystem of TPD. The twofold approach presented here represents a unique opportunity to analyse the role of teachers and their professional development in designing, implementing and assessing student learning in relation to digital technology, and offers insight into how teachers perceive their own professional development, whether as a means of improving and enhancing their skill set or as a way of substituting and instrumentalising them in the name of innovation.

2. Materials and Methods

2.1. Design

The research was based on two studies conducted at the same school. The research design for the first consisted of a descriptive–comparative [65] ex post facto analysis of a purposive sample. The second was based on a quasi-experimental pre-test/post-test design and was conducted using four experimental groups (divided by educational level) and no control. Both studies were conducted with the informed consent of the school.

2.2. Participation

The total sample for the two studies comprised 727 students from a single charter primary and secondary school situated in the region of Galicia. Spanish charter schools are independently run, publicly funded and tuition-free until the end of junior secondary school. The host school for the study offers all levels of education, from early childhood, through primary and junior secondary, right up to non-compulsory senior cycle. The total sample for the research drew on subjects from all levels of compulsory education: the sample for the first study comprised 443 students from primary 5th and 6th classes, and secondary 1st, 2nd, 3rd and 4th years, while the second study involved a sample of 284 students from primary 1st, 2nd, 3rd and 4th classes.

2.3. Instrument

The instrument used for the first study consisted of a questionnaire designed to assess the appropriateness of digital technology use by students and their perception of risk [66,67]. The instrument was reviewed by five experts [68], reliability was assessed according to Cronbach's alpha and an exploratory factor analysis was also performed [69]. The questionnaire contained 39 items, divided into 5 dimensions: habits of use (7), content and downloads (6), data management (8), relations with other users (10), and publications (8). Each item asked respondents about their frequency of inappropriate use (1 = Never, 2 = Rarely, 3 = Often, 4 = Always) and perceived level of risk (1 = Low, 2 = Medium, 3 = High). The instrument showed an internal reliability consistency of 0.90 across all of the items related to inappropriate use and 0.98 in relation to perceived risk.

The second study used Basic Maths Operations Task (BMOT) [70,71] to measure students' mathematical fluency in relation to a series of basic mathematical operations. The instrument was applied as published with students in 3rd and 4th classes (addition, subtraction, multiplication and division), and adapted to match the educational curriculum of participants from 1st and 2nd. The instrument calculated the number of operations completed by each student in a maximum time of one minute. Individual scores were recorded after each use as a gauge of mathematical fluency and improvement over time. The software also provided data with regard to number of activities completed and days of use.

2.4. Procedure

The two studies were conducted during the academic year 2019–2020, just before the declaration of the COVID-19 pandemic and public lockdown. The host school provided its full consent and collaboration in both interventions, and the class teachers were responsible for applying the instruments. The school also considered the studies useful to its educational practice, as a source of information on which to base its decision-making processes with regard to the use of digital technology and adjustments to the existing improvement plan.

2.5. Data Analysis

Data analysis was conducted using SPSS v. 25 and Prism v. 9. Descriptive analysis was used to find percentages and measures of central tendency and dispersion. Since the data collected were not parametric, a Kruskal–Wallis H test was used for the first study to identify significant statistic differences ($p < 0.5$) between year groups and to calculate the overall effect size (E_R^2) [72]. The second study compared pre-test and post-test scores using the Wilcoxon signed-rank test, with a significance level of 0.05, and used the Mann–Whitney U test to compare differences between independent groups. Effect size was calculated using the formula $r = |z| / \sqrt{N}$ [73] and interpreted based on the relevant literature in this area [74]. Degree of association between the variables analysed was calculated using Spearman's rho (r_s).

3. Results

3.1. Digital Technology and Adolescents: When Teachers Think Students Are Becoming More Competent Than They Are

Contrary to expectations, the results of the first study showed increasing rather than decreasing inappropriateness of use of digital devices in relation to increasing educational level (5th–6th P: $n = 180$, M = 1.23, Mdn = 1.21, DT = 0.183; 1st–2nd ESO: $n = 124$, M = 1.42, Md = 1.38, SD = 0.299; 3rd–4th ESO: $n = 101$, M = 1.71, Md = 1.69, SD = 0.294), with statistically significant differences between year groups and a strong effect size ($n = 405$, H(2) = 159.196, $p < 0.001$, $E_R^2 = 0.39$). The results are particularly surprising given the significant efforts by the school to improve digitisation and DC among its students, including: a staged improvement plan for late primary and early secondary school students; digitised, paperless classrooms (use of Chromebooks, tablets and computers); participation in awareness-raising programmes about responsible internet use run by the Department of Education and the College of Computer Engineers of Galicia; and talks by the police about internet safety and addiction. None of this seems to be working, however, as reflected by the decreasing levels of risk perception in relation to level of education (5th–6th P: $n = 180$, M = 2.17, Md = 2.46, SD = 0.674; 1st–2nd ESO: $n = 98$, M = 1.95, Md = 2.10, SD = 0.598; 3th–4th ESO: $n = 91$, M = 1.75, Md = 1.87, SD = 0.484), with statistically significant differences between year groups once again, though with a smaller effect size ($n = 369$, H(2) = 41.419, $p < 0.001$, $E_R^2 = 0.11$). These contradictory trends are illustrated in Figures 1 and 2:

The results indicate that the actions taken by the school have had little impact with regard to the development of structural skills and learning related to DC. On the contrary, the students' use of the digital technologies available to them points to the absence of skills training or an effective skills development plan. These deficiencies become more apparent when students begin to use technology autonomously: while students in late primary showed more responsible attitudes and less inappropriate use behaviour (Figure 3), their peers in secondary school showed progressively less awareness of the risks associated with inappropriate use of technology (Figure 4).

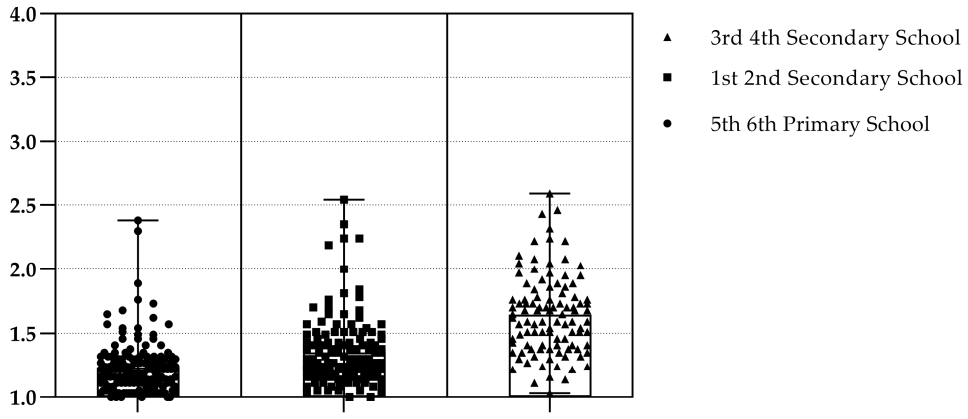

Figure 1. Overall frequency of inappropriate use of technology by level of education (1 = Never, 2 = Rarely, 3 = Often, 4 = Always).

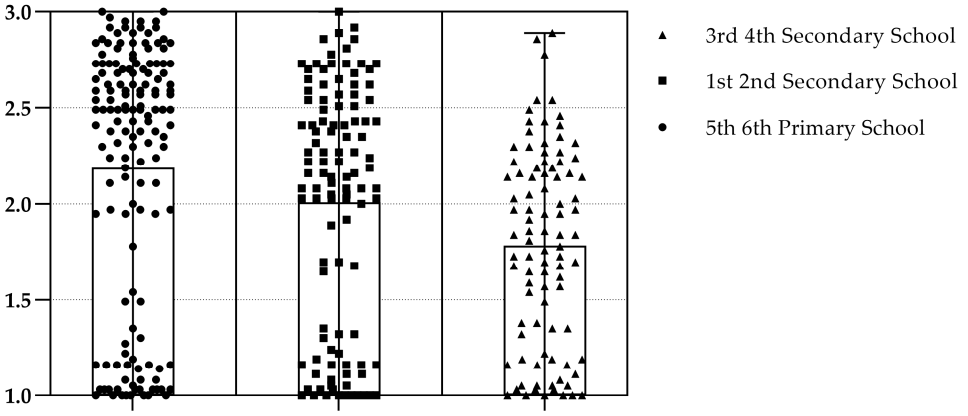

Figure 2. Overall level of risk attributed to inappropriate use of technology by level of education (1 = Low, 2 = Medium, 3 = High).

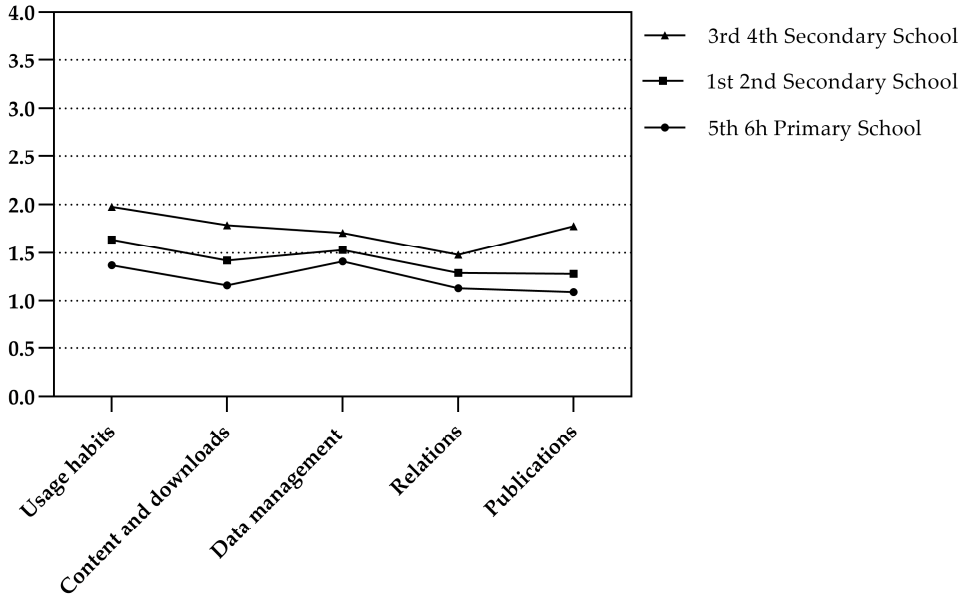

Figure 3. Average frequency of inappropriate use of technology by dimension and level of education (1 = Never, 2 = Rarely, 3 = Often, 4 = Always).

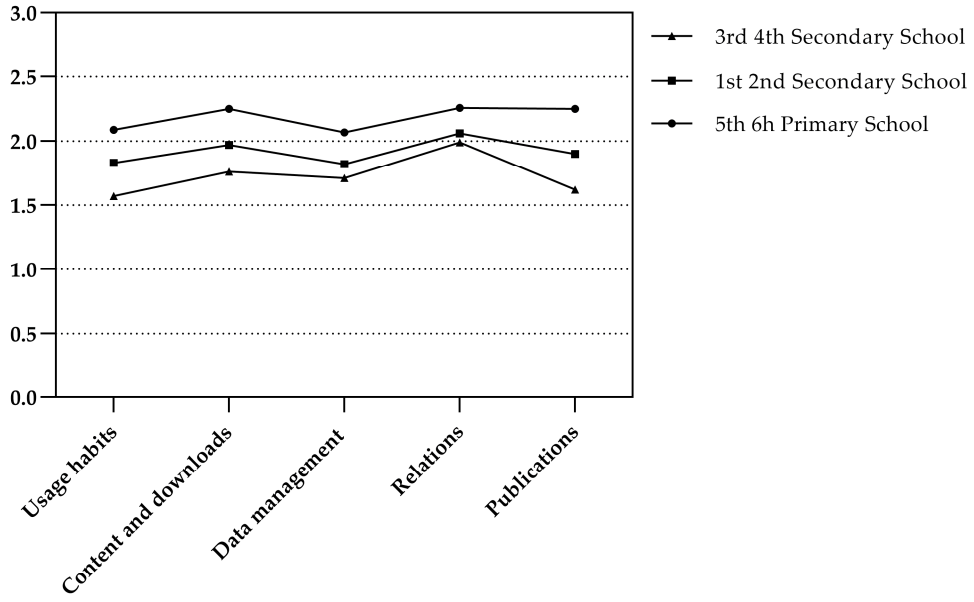

Figure 4. Average perception of risk by dimension and level of education (1 = Low, 2 = Medium, 3 = High).

The results of the study also reveal numerous issues in relation to TPD in terms of the teachers' inability to react to the unanticipated failure of their measures to promote student DC. The data returned to the school brought the problem to the teachers' attention, but also highlighted their inability to tackle or solve it. The concept of teachers as researchers which is central to TPD, and the skills and knowledge set that requires, are absent from their training, which leads them to adopt measures related to DC which lack the necessary prior critical reflection or engagement. It is not merely a question of organising complementary activities for students or replacing textbooks with tablets. Teachers must also play a central role in promoting lasting learning and possess the training necessary to do so. Innovation cannot take place unless teachers develop the professional autonomy to identify problems and activate the resources necessary to deal with them.

3.2. Serious Games and Gamification: Buying and Selling Innovation

The second study conducted at the school involved the use of serious games as a means of improving mathematical fluency. In this case, the school did not design the learning activity, but merely purchased an educational software product as a way of digitising the methodology used in the classroom. Teachers were not given any kind of training (either compulsory or voluntary) and played no teaching role in the activity. Furthermore, while the software changed the medium of learning for the students, in an attempt to make the activity more fun and engaging, the overall pedagogical approach remained largely unchanged. The study covered a period of four months, from pre-test to post-test, during which the teachers allowed students to use the software for a specified amount of time 2–3 days per week, resulting in an average of 27 days per teacher over the course of the study. The software included a recommended minimum daily play time to optimise user engagement with the game, leading to an average of 5747 activities by each student.

The results showed a high magnitude of improvement between students' pre-test and post-test performance (n = 284; Z = −14.291, p = 0.000; r = 0.60), with average scores rising from 8.99 pre-test to 17.79 post-test. The improvement observed was associated with the number of operations completed (r_s = 0.82; p = 0.000) and the amount of time spent playing the game, as highlighted by the breakdown of results by year group (first: r_s = 0.20, p = 0.108; second: r_s = 0.36, p = 0.002; third: r_s = 0.39, p = 0.001; fourth: r_s = 0.40, p = 0.001). Finally, a moderate improvement was observed in relation to the number of activities completed (first: r_s = 0.37, p = 0.002; second: r_s = 0.65, p = 0.000; third: r_s = 0.48, p = 0.000;

fourth: $r_s = 0.48$, $p = 0.000$). The breakdown by year group shows a high magnitude of improvement between pre-test and post-test scores in all cases, as illustrated in Table 1: first: Z = −7.225, $p = 0.000$, r = 0.62; second: Z = −7.378; $p = 0.000$, r = 0.61; third: Z = −6.354, $p = 0.000$, r = 0.53; fourth: Z = −7.251, $p = 0.000$, r = 0.61.

Table 1. Descriptive data by primary school year group.

	Pre-Test Scores			Post-Test Scores			Days of Use			Number of Activities		
	M	**Md**	**SD**	**M**	**Md**	**SD**	**M**	**Md**	**SD**	**M**	**Md**	**SD**
1st (n = 69)	2.97	2	3.16	12.80	13	5.43	28.3	27	4.9	5662.4	4775	2829.6
2nd (n = 72)	8.64	8	3.651	20.99	20.5	8.139	29.6	28.5	6.1	6775.5	5733.5	3918.5
3rd (n = 73)	10.64	10	4.66	15.45	15	5.71	29.4	29	8.7	6620.1	6344	3315.3
4th (n = 70)	13.57	13	6.04	21.84	21	6.52	21.3	20.5	5.2	3865.4	3445	1890.6

Figure 5 illustrates the improvement between pre-test and post-test scores by year group.

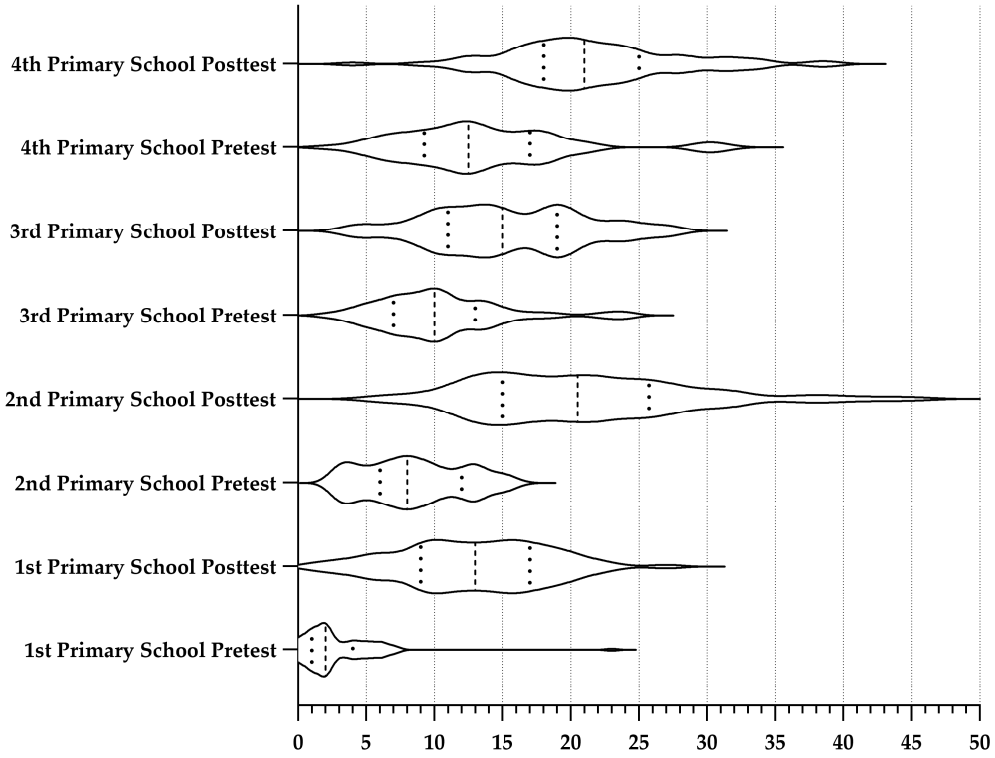

Figure 5. Differences between pre-test and post-test scores by educational level.

The software used by the school also includes an interactive practice games option, designed to reinforce student performance and motivation. Not all of the teachers use this option, however. In relation to the impact of these practice games on student performance, the results show a significant difference between the groups that received additional practice and those that did not (RYes = 158.68; RNo = 109.80; Z = −4.729, $p = 0.000$; r = 0.28). The groups that played the additional games used the software more often and carried out more activities. The results for both variables showed a significant difference between the two groups and a medium effect size (days played: RYes = 164.82; RNo = 97.39; Z = −6.517, $p = 0.000$, r = 0.39; activities carried out: RYes = 157.58; RNo = 112.02; Z = −4.399, $p = 0.000$, r = 0.26).

The experience reveals a contradiction between the success achieved in terms of student performance and the lack of any equivalent improvement or innovation on the

teachers' part. There is no research into the teaching methodologies used prior to the introduction of the software, no systematic analysis of the teachers' teaching practice, no critical reflection regarding the process of change and improvement, all of which are essential from the perspective of TPD. The software is marketed as a complete learning product which promises and delivers improvement; the teachers do not need to know how it works, merely that it does. In the first experience, the teachers attempted to design a strategy to promote responsible use of and attitudes towards technology among students, but failed. Here, by contrast, the purchase of educational software to promote mathematical fluency shows positive results, but at the same time externalises learning and risks creating a dependency on monetised technological solutions. With the advance of educational technology, therefore, comes the danger of schools being colonised by private companies and teachers being progressively deprofessionalised.

4. Discussion and Conclusions

The basic aim of this research has been to explore the relationship between technology-based education and teacher professional development in order to examine the role of teachers in the innovation process and the impact of digital innovation on their teaching practice. The two studies reported here examine the role of teachers in the innovation process and the impact of digital innovation on their teaching practice. The research is based on the consensus assumption among researchers of the essential role of teacher professional development in the improvement of teaching and learning: 'what teachers learn while teaching, which is what professional development is, is critical for them and highly influential on students' educational experience and learning' [1].

The article reports the empirical findings of two studies conducted at the same school with the aim of analysing the professional development of the teachers working there: firstly, the outcomes of an improvement plan designed by the teachers themselves, aimed at promoting responsible, critical use and risk awareness of digital technology among students; secondly, the impact on academic performance of a bought game-based educational software product for the improvement of mathematical fluency.

The results in relation to DC and responsible use of digital technology raise important questions regarding the role of teacher professional development. The EU's recommendations on key competences for lifelong learning [75], its specific frameworks for DC [56,76] and the LOMLOE education reform that transposes those guidelines into Spanish law [55] all fall short in their objectives of competence building and school success. While the studies conducted at the school have made the teachers there more aware of the situation, they lack the necessary professional development supports and resources to address the problem [1], and therefore remain trapped by ineffective improvement processes that do not contribute to either student learning or critical reflection about their own professional practice. The challenge facing them is undoubtedly complex [77,78], but that is no reason not to explore systematic forms of inquiry to improve both student and teacher learning. Mere participation in training processes is not sufficient: what teachers need is real learning based on critical reflection about the assumptions on which their professional practice is founded and reconstruction of their professional knowledge in order to interpret the realities facing them [11]. In its absence, the situation of uncertainty provoked by the results of the first study is translated not into an opportunity for professional development, but into a sense of inadequacy and inability to generate contextualised knowledge based on their own experience and research [12,15,17,18,21]. The study thus highlights the importance of TPD as well as the consequences of not fomenting the role of teachers in the educational inquiry process [21,79]. Stenhouse [17] (p. 144) contrasts the limited role and autonomy of this kind of 'restricted professionalism' with the 'capacity for autonomous professional self-development through systematic self-study, through the study of the work of other teachers and through the testing of ideas by classroom research procedures'. Advances in research on professional learning and development have demonstrated the need for teachers to participate in communities of practice to share and compare their everyday

professional experiences. The conceptualisation of teachers as researchers and producers of knowledge likewise requires a greater awareness of the reality of the teaching profession on the ground, and an acknowledgement that teachers are the people best qualified to decide where teaching and learning can be improved and how to achieve it. Those changes have yet to happen.

The second study highlighted a clear contradiction with regard to professional development. Improvement in students' mathematical fluency was achieved by simply acquiring a serious game software product and setting it in motion. The differences between pre-test and post-test scores were significant and of high magnitude. These results are in keeping with the findings of previous studies [59–61] which confirm the potential benefits of this type of strategy. However, the element driving change and creating an image of innovation and modernity in this instance was the technology itself, not the teachers. The problems teachers encounter in relation to their technological professional development stem from deficiencies in their initial [40] and ongoing training, and from the classroom reality itself, where teaching remains focused on transmissive rather than transformative models [42,44]. The impact of this on student learning is clearly detrimental [57,80]. The study illustrates the symbolic role of digital technology as an indicator of educational improvement and innovation [81], but also the absence of any associated strengthening or promotion of teacher professional development.

The growing presence of technological innovation in education has transformed the educational landscape and brought with it challenges and contradictions for students and teachers alike. The studies reported in this article highlight the paradoxical appearance of innovation alongside the absence of professional development. The first study, regarding responsible use and risk perception, revealed serious shortcomings in the development of students' DC despite a series of actions and measures by the school, and the inability of teachers to find an effective solution. In the second, the use of serious games and gamified learning resulted in quantifiable academic success among students, but involved no questioning of assumed pedagogical models and no significant transformation of the teachers' practice. TPD remains an elusive challenge, but it is the key to unlocking the teaching skills needed to navigate the maze of digital technology.

As in all studies, certain limitations must be acknowledged. Firstly, the possibility of conducting both studies across different year groups within a single school allowed us to obtain a clearer picture of the implications of TPD. However, the quantitative methodology used in both cases was only able to illustrate the contradictions detected, without providing more contextual, explanatory insight into their implications for teachers. In addition, the research only describes the situation at the school at the time of the studies, but does not provide any follow-up data regarding actions taken by the school in response to the findings or changes in the teachers' practice.

The findings of this study pose a challenge for future researchers to examine and promote the role of teachers as the conscious, responsible leaders of pedagogical innovation both at a school level and within the wider education system.

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Informed Consent Statement: Informed consent was obtained from the participating school on behalf of all of the students. Individual participant consent was not required because the research did not involve any personal data.

Data Availability Statement: All data are available on the request to the corresponding author.

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