COLLABORATIVE WORK TO CROSS SUBJECT BOUNDARIES WITH DIGITAL TECHNOLOGIES: DEVELOPING A TRAINING PLAN THROUGH ACTION RESEARCH

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Abstract

This article describes Cycle II of a set of three action-research cycles designed as part of an educational research project. It aims to contribute to a deeper understanding of how teachers collaborate and learn from each other in their professional contexts, fostering collaborative planning practices that aim to articulate the work of various subject areas with digital technologies. In this sense, this cycle was dedicated to developing a training intervention with characteristics of the F@R Model (Training-Action-Reflection), with the aim of involving teachers in joint work. It sought to provide more or less structured learning moments for these professionals to become agents of change, experimenting, testing and discussing new pedagogical approaches. To be operationalised, this cycle was guided by two research questions: 1) How is the articulation between different areas and curricular elements revealed in the planning conceived in a structured training context? and 2) How are digital technologies reflected in the planning of collaborative teaching activities? The innovation of this work lies above all in terms of methodology in this area of study and intervention. The empirical component was developed through an in-service training course lasting 38 hours. The participants were ten teachers from the 2nd cycle of basic education in Portugal (equivalent to ISCED 2), which covered at least two of a number of disciplines, in an interdisciplinary logic. The data was collected from the planning, collaborative work sessions and reflections of the participating teachers. Content analysis was favoured, using categories and frequencies. The collaborative work sessions led the teachers to negotiate a common planning model. They were able to develop joint planning, prioritising the articulation between different subjects, which brought together areas such as Mathematics, Natural Sciences, Citizenship and Development, and ICT (Information and Communication Technologies). These synergies materialised in various pedagogical strategies, with the use of digital tools and the exploration of problem situations that promoted broader, more integrative and meaningful learning experiences. However, there were still challenges in designing strategies in an interdisciplinary way, since the existing curriculum documents are still structured in a fragmented way. On the other hand, the planning also included the creation of opportunities for students to experiment with the potential of digital technologies in concrete situations, deviating from the initial conception that digital technologies would be restricted to the ICT subject. Participants emphasised the usefulness of mutual feedback during the sessions, highlighting continuous improvement, self-efficacy and changes in practice. These results show that structured and reflective training sessions can lead to innovative educational practices in harmony with inter- and transdisciplinary pedagogical approaches. This will support collaborative work to plan inter- and transdisciplinary pedagogical strategies with digital technologies in the future.

Keywords: Collaborative work, teacher professional development, pedagogical strategies with digital technologies, action research, F@R Model, pedagogical planning.

1 INTRODUCTION

Digital advances and curricular innovations have brought challenges to educational organisations, and organisational learning is essential to cope with these stimuli [5]. Collaboration among teachers is emphasised as a way of working and a learning scenario, promoting self-efficacy and investment in professional development [10, 20]. Working collaboratively fosters trust and the sharing of common goals, and it is necessary to create the conditions to innovate in training and integrate digital technologies into teaching practices [17, 22].

Interdisciplinarity and transdisciplinarity are relevant approaches for reconfiguring teachers' practices, integrating knowledge to educate students in an integral way [7, 16]. Transdisciplinarity goes beyond disciplines, promoting the construction of holistic knowledge [9]. In the context of the European

Framework for the Digital Competence of Educators – DigCompEdu, professional collaboration is an essential competence, emphasising the use of digital to share practices and innovate [4].

Despite its importance, collaboration among teachers is limited, often restricted to sharing materials and ideas, while more in-depth practices such as joint planning and feedback are rare [18, 21]. The research suggests the need to further explore how teachers interact and learn together, especially in Portugal, where there are gaps in the integration of digital tools into collaborative strategies [13].

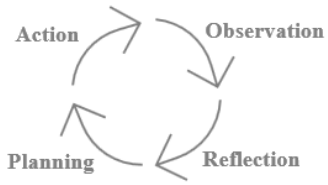
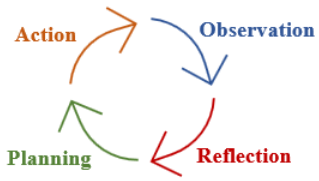
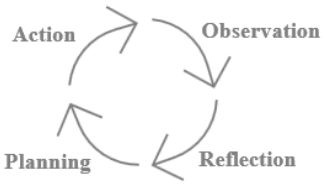
Localised teacher training in pedagogical and technological innovation projects is highlighted as essential [1, 2]. Models such as F@R – Training-Action-Reflection – promote a structured approach, with stages that include planning, implementation, reflection and practical application [6]. Within the scope of this work, a group of 10 teachers took part in an action-research cycle, favouring critical reflection and significant changes in teaching practices, promoting the effective use of digital technologies and contributing to the construction of collaborative networks [15].

2 METHODOLOGY

The epistemological and methodological references that underpin this work are anchored in the assumptions of the qualitative and critical paradigms, with action research being the central methodological option, operationalised in three self-reflective cycles [8, 11, 19].

This article focuses on Cycle II, called “Intervention”, which integrated and valorised the results of the previous cycle, and was guided by two research questions: 1) How is the articulation between different areas and curricular elements revealed in the planning conceived in a structured training context?; and 2) How are digital technologies reflected in the planning of collaborative teaching activities? The answer to these questions followed a plan structured in four stages – Planning, Action, Observation and Reflection, as shown in Table 1.

Table 1. Action Research Cycle.

Cycle I →	***Cycle II*** →	*Cycle III*
Diagnosis Understanding the conceptions and practices prior to the intervention	**Intervention** (F@R Model)	**Evaluation** Understanding the effects of training
		
Q1 – Q2*	Q3 – Q4*	Q5 – Q6*
Diagnostic interviews; planning.	Planning; collaborative work sessions; teacher reflections.	Semi-structured interviews; planning (6 months after the intervention).

**They refer to research questions.*
Source: Elaborated by the authors.

It should be emphasised that the study was previously approved by the Ethics Committee of the Institute of Education of the University of Lisbon, which confirmed compliance with fundamental ethical principles and guidelines. In addition, the General Data Protection Regulation [23] and European Union regulations were followed. The informed, free and informed consent of the participants and the authorisation of the institution where the research took place were also obtained.

Recalling the focus on Cycle II, we continue with a descriptive presentation of each of the stages.

2.1 Planning

Based on the results obtained in Cycle I [14], it was thought that a collaborative training context would be the ideal field to meet the needs and expectations of the participants, and in accordance with the prioritised

theoretical bases. The systematised information showed that the participants valued collaborative work, as well as inter- and transdisciplinary practices, although they did so informally. Thus, it was realised that the development of pedagogical strategies would benefit from more structured planning, making it possible to articulate, with formality and more evident intentionality, the work of various subject areas with digital resources. Also noteworthy is the intention of pedagogical isomorphism and the expectations of professional development in context.

In this way, the training was designed to be a strategic action, in which collaborative planning, reflection and the practical implementation of training interventions would take place in an integrated way, providing a training-action-reflection environment, with characteristics of the F@R Model. The plan, which lasted 38 hours, was organised into 10 face-to-face sessions (25 hours in total) and autonomous work (13 hours). In addition, in conjunction with the School Training Centre in the area where the research took place, it was decided that the participants would primarily be from the Mathematics and Natural Sciences subject group, which could also include the Citizenship and Development subject, in an interdisciplinary logic. As for the data collection plan, it was considered relevant to collect evidence from planning, collaborative work sessions, participants' reflections, field diaries and student productions, the latter two being complementary information gathering processes. However, the work described here focuses exclusively on analysing the plans that the participants produced during the training.

2.2 Action

The training planned and described in the previous stage took place from February to May 2024 and involved 10 teachers from the 2nd cycle of basic education, corresponding to the International Standard Classification of Education - Level 2 (ISCED 2), who voluntarily joined the study. Once the participants' registrations had been formalised, the face-to-face working sessions went ahead.

In the first session, data was collected on the characterisation of the participants, with eight aged between 41 and 50, one aged up to 25 and one over 51. In terms of gender, seven were female and three were male. With regard to the number of years of service, six have between 7 and 25 years of service, three have between 1 and 3 years of service and one has between 26 and 35. With regard to academic qualifications, eight have a bachelor's degree and two have a master's degree. The participants came from six different schools. As for the subjects taught in the school year in question, three taught Mathematics and Natural Sciences, two only Natural Sciences, two taught Mathematics and Citizenship and Development, one taught Natural Sciences and Citizenship and Development, one taught Mathematics, Natural Sciences and Citizenship and Development, and one taught only Mathematics.

Also in the first session, in addition to characterising the participants, a questionnaire was administered to diagnose their practical conceptions and motivations on the thematic in question, making it possible to make minor adjustments to the initial structure of the training plan. The results of the previous cycle, the various elements of the training (objectives, content, work proposals and assessment) and the support platform, in this case Moodle, were also presented. It was planned that at the end of each session there would always be room for reflection on the work carried out.

Session 2 explored core concepts, inter- and transdisciplinary pedagogical approaches, in line with the curricular guidelines for each of the subject areas and the official guiding documents. The F@R Model was introduced in session 3, followed by the exploration of environments involving digital technologies for the design of pedagogical strategies. Session 4 saw the joint negotiation and adaptation of a proposal for a model to guide the planning of pedagogical strategies with digital technologies, which was called “Inter and Transdisciplinary Pedagogical Strategy with Digital Technologies”. Also in session 4, working groups were organised in pairs to develop collaborative planning, centred on the needs felt by the participants in their work contexts.

In sessions 5 and 6, the participants worked collaboratively to plan pedagogical strategies based on the problem situations identified, shared their products and received suggestions from their colleagues for adjustments and improvements. During sessions 7 to 9, the focus was on reflection, evaluation and reformulation of pedagogical strategies, taking into account the results obtained in practice. Finally, in session 10, the results of a second planning session were shared, once they had been implemented in teaching practice, and a final evaluation of the training was made.

Autonomous work involved putting the pedagogical strategies devised collaboratively into practice with the students. This work also included reflecting on the results obtained, resulting in the preparation of documents showing the effects of the strategies applied.

This stage culminated in the assembly of 10 collaboratively devised plans, summarised in Table 2.

Table 2. Collaboratively designed plans.

Code	Participants	Title of Pedagogical Strategy	Duration (Minutes)	Subjects involved*				
				M	NC	CD	ICT	HGP
P1	AE	In April, we'll be painting carnations!	135	X	X			
P2	BC	Nature's solids with digital.	90	X		X		
P3	FG	Nature's Tangram.	300	X	X	X		
P4	HI	Recipes and proportions.	135	X	X	X		
P5	JK	Mathematics and biodiversity in the garden.	180	X	X	X		
P6	AE	Plants, symmetries and endless rotations.	225	X	X			
P7	BC	Discovering sequences - sequences with matches.	90	X		X		
P8	FG	AGAN around the world.	250	X		X		X
P9	HI	Whatsapp_Data.	100	X		X	X	
P10	JK	Mathematics and sustainability through the air.	180	X	X	X		

**M – Mathematics; NC – Natural Sciences; CD – Citizenship and Development; ICT – Information and Communication Technologies; HGP – History and Geography of Portugal.*

Source: Elaborated by the authors.

2.3 Observation

This stage consisted of preparing tools to systematically analyse the information gathered in the previous stage, that is by reference to the research questions. To this end, an analysis matrix was developed, organised into two analytical dimensions: 1) Combinations between different subject areas and curricular elements; and 2) Uses and functions of digital technologies. The first dimension included five analytical categories: curriculum articulation; pedagogical approaches between subject areas; learning situations; assessment model; and level of student participation. The second dimension included only two categories: uses and functions of digital technologies; and digital tools mobilised.

It should be noted that this matrix, which resulted from this phase, underwent several reformulations and was validated by the scientific coordination team, whose role can be likened to that of judges [3].

2.4 Reflection

Based on the material gathered and systematised, a qualitative analysis of the plans was carried out, based on thematic analysis [12]. The results were organised in frequency distribution tables - absolute (N) and relative (%). Each table reflected the presence or absence of each indicator, counting its presence only once, per plan where it had been identified. It also reflected the frequency with which a given indicator was highlighted in all the plans (P1 to P10), in the context of a given category, by dimension. “N” referred to the absolute frequency (total number of occurrences of each indicator) and “%” indicated the relative frequency (percentage relative to the total number of plans).

3 RESULTS

3.1 Combinations between different subject areas and curricular elements

Regarding the first dimension, aligned with the first research question – “How is the articulation between different areas and curricular elements revealed in the planning conceived in a structured training context?,” five analytical categories stood out, namely: curriculum articulation; pedagogical approaches between subject areas; learning situations; assessment model; and level of student participation.

In relation to the “curriculum articulation” category, the analysis enabled the identification of 6 indicators, shown in Table 3.

Table 3. Curriculum articulation.

Categories	Indicators	Pedagogical Planning										P	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N	%
Curriculum articulation	Involves two subject areas	X	X				X	X				4	40%
	Involves more than two subject areas			X	X	X			X	X	X	6	60%
	Articulation within the subject group	X		X	X	X	X				X	6	60%
	Articulation beyond the subject group		X	X	X	X		X	X	X	X	8	80%
	Explicit connections between subject areas	X		X	X	X	X	X	X	X	X	9	90%
	Developing transversal skills	X	X	X	X	X	X	X	X	X	X	10	100%

Source: Elaborated by the authors.

All the plans analysed and designed collaboratively (N=10) presented the “developing transversal skills” (100%). Almost the majority also highlighted “explicit connections between subject areas” (90% of the plans), closely followed by “articulation beyond the subject group” (80%). More than half of the plans included “articulation within the subject group” and “involves more than two subject areas” (both found in 60% of the plans). Next, emphasis was placed on articulation that “involves two subject areas” (40% of plans). None of the plans favoured a strictly disciplinary approach. However, in the participants' collaborative reflection, it was possible to see that there are still challenges, as we read: “There should be greater freedom to approach the content in a global way and not in a compartmentalised way, as we were initially tempted to do.”

With regard to the “pedagogical approaches between subject areas” category, the analysis identified 5 indicators, as shown in Table 4.

Table 4. Pedagogical approaches between subject areas.

Categories	Indicators	Pedagogical Planning										P	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N	%
Pedagogical approaches between subject areas	Characteristics of project work			X		X			X			3	30%
	Based on experimental activity	X										1	10%
	Based on digital technologies	X	X	X	X	X	X	X	X	X	X	10	100%
	Fieldwork		X									1	10%
	Problem situations			X	X	X	X	X	X	X	X	8	80%

Source: Elaborated by the authors.

As you can see, all the lesson plans include pedagogical approaches “based on digital technologies” (100%). Approaches based on identified “problem situations” were also widely identified (80% of plans). There were also “characteristics of project work” approaches (30%), followed by “based on experimental activity” and “fieldwork” situations (both suggested in 10% of the plans). Digital technologies have played a central role. Pedagogical approaches based on problem situations and project work were also emphasised. The overarching themes were the Sustainable Development Goals, biodiversity, healthy eating and interculturality. From the participants' perspective, these were relevant “for defining an integrating element” between subject areas.

In terms of the “learning situations” category, the analysis identified 24 indicators, shown in Table 5.

Table 5. Learning situations.

Categories	Indicators	Pedagogical Planning										P	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N	%
Learning situations	Experimental activity	X										1	10%
	Photography activity		X				X					2	20%
	Data selection, collection and processing	X	X	X	X	X	X		X	X	X	9	90%
	Ethical use of data			X					X			2	20%
	Email writing								X			1	10%
	Report preparation	X										1	10%
	Drawing up a poster			X								1	10%
	Digital poster creation					X		X			X	3	30%
	Preparation of a digital presentation						X					1	10%
	Restructuring of the student´s work	X			X		X					3	30%
	Online publication		X		X							2	20%
	Creation of digital geometric models	X	X	X			X					4	40%
	Geometric construction/maquette			X								1	10%
	Creating a digital questionnaire			X						X		2	20%
	Providing digital feedback			X					X	X		3	30%
	Creation of a digital concept map				X							1	10%
	Glossary construction				X							1	10%
	Worksheet				X	X		X			X	4	40%
	Making recipes				X							1	10%
	Upload photos					X	X					2	20%
	Collection of reusable materials							X				1	10%
	Drafting a collective text								X			1	10%
	Organising data in Excel							X	X	X	X	4	40%
	Creation of a digital world map								X			1	10%

Source: Elaborated by the authors.

Continuing to look at the indicators, the most prominent learning situations were related to “data selection, collection and processing” (in 90% of the plans). “Creation of digital geometric models”, “worksheets” and “organising data in Excel” appeared in almost half of the plans (all 40%). Next, activities such as “digital poster creation”, “providing digital feedback” to students and “restructuring of the student´s work” were found in 30% of the plans. “Photography activity”, “ethical use of data”, “online publication”, “creating a digital questionnaire” and “upload photos” were also included in the learning situations in 20% of the plans. And a small minority of the plans (10%) incorporated “experimental activity”, “email writing”, “report preparation”, “drawing up a poster”, “preparation of a digital presentation”, “geometric construction/maquette”, “creation of a digital concept map”, “glossary construction”, “making recipes”, “collection of reusable materials”, “drafting a collective text”, and “creation of a digital world map”. It reveals the diversity of learning situations that can be conceived collaboratively, highlighting trends and preferences.

As for the “assessment model” category, the analysis identified 7 indicators, as shown in Table 6.

Table 6. Assessment model.

Categories	Indicators	Pedagogical Planning										P	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N	%
Assessment model	Diagnosis	X				X			X		X	4	40%
	Restructuring of the student´s work	X			X		X					3	30%
	Overview	X	X	X	X		X	X	X			7	70%
	Digital student feedback			X					X	X		3	30%
	Teacher feedback									X		1	10%
	E-Portfolio					X					X	2	20%
	Digital quiz							X				1	10%

Source: Elaborated by the authors.

As you can see, the favoured form of assessment was the “overview”, which featured in more than half of the plans (70%). This was followed by “diagnosis” assessment in almost half (40% of the plans). Situations such as “restructuring of the student´s work” and “digital student feedback” also appeared in 30% of the plans. In addition, the “E-Portfolio” was emphasised in 20% of the plans. “Teacher feedback” and “digital quiz” also appeared in 10% of the plans. There was a predominance of formative assessment. Only one plan was orientated towards summative assessment (10%), although it also included formative assessment. In turn, more than half (60% of the plans) showed an approach related to the assessment of digital learning.

With regard to the category “level of student participation”, the analysis enabled the identification of 4 indicators, expressed in Table 7.

Table 7. Level of student participation.

Categories	Indicators	Pedagogical Planning										P	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N	%
Level of student participation	Autonomy in learning	X	X	X	X	X	X	X	X	X	X	10	100%
	Collaboration among students	X	X	X	X	X	X	X	X	X	X	10	100%
	Family involvement		X		X							2	20%
	Teacher-led strategy	X	X	X	X	X	X	X	X	X	X	10	100%

Source: Elaborated by the authors.

In all the plans (N=10) the following indicators were found with regard to the level of student participation: “autonomy in learning”, “collaboration among students” and “teacher-led strategy”. “Family involvement” also appeared in 20% of the plans. It was in the sense of autonomy in learning that the teachers revealed that the students went beyond what was asked of them, “having installed the Pl@ntNet application on their mobile phones and photographed some of the school's flowers immediately after the project was presented.”

3.2 Uses and functions of digital technologies

Regardind the second dimension, aligned with the second research question – “How are digital technologies reflected in the planning of collaborative teaching activities?,” Two analytical categories stood out: uses and functions of digital technologies; and digital tools mobilised.

In relation to the category “uses and functions of digital technologies”, the analysis enabled the identification of 9 indicators, shown in Table 8.

Table 8. Uses and functions of digital technologies.

Categories	Indicators	Pedagogical Planning										P	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N	%
Uses and functions of digital technologies	Exploring curriculum content	X	X	X	X	X	X	X	X	X	X	10	100%
	Developing transversal skills	X	X	X	X	X	X	X	X	X	X	10	100%
	Representation of abstract concepts	X	X				X					3	30%
	Visibility of work		X		X		X	X				4	40%
	Summative assessment							X				1	10%
	Collection of student feedback			X					X	X		3	30%
	Data collection and processing							X	X	X	X	4	40%
	Collaboration among students				X							1	10%
	Pedagogical innovation	X	X	X	X	X	X	X	X	X	X	10	100%

Source: Elaborated by the authors.

All the plans (N=10) emphasised the following uses and functions of digital technologies: “exploring curricular content”, “developing transversal skills” and “pedagogical innovation”. In almost half of the documents analysed (40%), digital tools were used both for processes involving the “visibility of work” and for the “data collection and processing”. These resources were also used to facilitate the “representation of abstract concepts” and the “collection of student feedback” (in 30% of the plans). The use of digital technologies for “summative assessment” and for “collaboration among students” was also revealed in 10% of the plans. From the participants' perspective, the students “concluded that it was easier to carry out the activity with GeoGebra than with the traditional method”, inferring that it facilitated the understanding of abstract content.

As for the “digital tools mobilised” category, the analysis identified 18 indicators, as shown in Table 9.

Table 9. Digital tools mobilised.

Categories	Indicators	Pedagogical Planning										P	
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N	%
Digital tools mobilised	GeoGebra	X	X	X			X					4	40%
	Virtual School	X										1	10%
	Digital Classroom							X				1	10%
	Pl@ntNet					X	X					2	20%
	Padlet		X		X					X	X	4	40%
	Plickers			X								1	10%
	Mentimeter			X					X	X		3	30%
	Camera		X				X					2	20%
	Microsoft PowerPoint				X		X		X	X	X	5	50%
	CmapTools				X							1	10%
	Google (search engine)			X	X					X		3	30%
	Microsoft Word			X		X						2	20%
	Toy Theater					X					X	2	20%
	Google Maps					X						1	10%
	Microsoft Teams					X					X	2	20%
	E-mail						X		X			2	20%
	Microsoft Excel							X	X	X	X	4	40%
	Google Forms									X		1	10%

Source: Elaborated by the authors.

As you can see, the digital tools mobilised were diverse. In half of the plans (50%) “Microsoft PowerPoint” was mobilised. This was followed by “GeoGebra”, “Padlet” and “Microsoft Excel”, resources that incorporated almost half of the plans (40%). “Mentimeter” and “Google” were also used as search engines (both in 30% of the plans). “Pl@ntNet”, “camera”, “Microsoft Word”, “Toy Theatre”, “Microsoft Teams” and “e-mail” were also used (in 20% of the plans). Last but not least, the digital tools used were “Virtual School”, “Digital Classroom”, “Plickers”, “CmapTools”, “Google Maps” and “Google Forms” (in 10% of the plans).

4 FINAL CONSIDERATIONS

Through a training intervention, this study sought to contribute to theoretical and empirical support for the importance of inter- and transdisciplinarity as approaches to fostering integration and collaboration between subject areas and forms of knowledge in a critical, reflective and transformative way. The main insights suggest that the collaborative work sessions led the teachers to negotiate a common planning model. They were able to develop joint planning, prioritising the articulation between different subjects, which brought together areas such as Mathematics, Natural Sciences, Citizenship and Development, ICT (Information and Communication Technologies), and History and Geography of Portugal. These synergies materialised in various pedagogical strategies, with the use of digital tools and the exploration of problem situations that promoted broader, more integrative and meaningful learning experiences [9]. However, there were still challenges in designing strategies in an interdisciplinary way, since the existing curriculum documents are still structured in a fragmented way. On the other hand, the planning also included the creation of opportunities for students to experiment with the potential of digital technologies in concrete situations, deviating from the initial conception that digital technologies would be restricted to the ICT subject. Participants emphasised the usefulness of mutual feedback during the sessions, highlighting continuous improvement, self-efficacy and changes in practice [15]. These results show that structured and reflective training sessions can lead to innovative educational practices in harmony with inter- and transdisciplinary pedagogical approaches. This will support collaborative work to plan inter- and transdisciplinary pedagogical strategies with digital technologies in the future.

The main limitation to these considerations is the small number of plans analysed, and it is suggested that future studies should expand the corpus of documents.

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