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Interdisciplinarity in Teacher Education: Evaluation of the Effectiveness of an Educational Innovation Project

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Abstract: Interdisciplinary projects play an important role in the development of a student profile based on the 21st century skills. Nevertheless, the implementation of an interdisciplinary approach is a challenge for both teachers and teacher educators. The aim of this study is to create an interdisciplinary model for teacher education, and to provide an empirical study which analyses its impact on learning. An educational innovation project was carried out with preservice teachers who experienced and subsequently designed a Problem Based Learning with interdisciplinary activities including Mathematics and Social Sciences, using the National Archaeological Museum as an educational resource. The proposals were implemented amongst children to evaluate the project's effectiveness, considering two aspects: (a) improved teaching skills for preservice teachers (N = 26) and (b) improved learning for Mathematics and Social Sciences content amongst primary school children (N = 58). In the case of the student teachers, the variance analysis implemented showed sufficient empirical evidence of the improvement between the pre and post treatment, in different dimensions of the teaching skills and competences. On the primary school students, some significantly statistic progresses were found concerning the learning of both subjects, as well as their perception of museums as place for learning.

Keywords: interdisciplinary approach; museums; teacher training; 21st-century skills; quality education; self-efficacy; active methodologies; college school cooperation; teacher collaboration

1. Introduction

This research project arises from the desire to continuously improve the quality of teacher education. Educating 21st century teachers requires coherent planning that is aligned to skills from this century. Putting an emphasis on collaboration, creativity, critical thinking and communication skills involves reflecting on the need for future teachers to recognise themselves as active and authentic subjects who are responsible for their own education process. This requires education research to include proposals that commit teachers to their own learning and allow them to develop the skills required to become a teacher [1,2]. Competency based education involves preparing students, not only so that they are capable of solving problems in different contexts, but also so that this problem solving can be more effective as a result of knowledge integration [2–6]. As a result, preservice teachers will be capable of effectively dealing with different social, personal, academic and professional situations.

As it is impossible to develop a teacher's skills profile based on a single subject, interdisciplinary projects play an important role in promoting competency-based learning, as well as meaningful learning and teaching quality for teacher education [7–9]. Furthermore, these types of projects encourage teacher collaboration and the development of communication skills, as they are not carried out from an individual perspective, but rather they involve ongoing exchanges and collaboration amongst all the different agents taking part in the education process [10,11].

However, despite the importance that interdisciplinary instruction has on teacher education, two important gaps have been identified: (a) one related to the lack of interdisciplinary projects carried out for teacher education; and another (b) related to the lack of empirical studies which analyse the effect of interdisciplinary proposals on students' learning.

Currently, the implementation of an interdisciplinary approach across all stages of the education system is a challenge both for teachers and for those who are educating the teachers. The majority of interdisciplinary projects have been carried out within elementary education [12–15] or secondary education [16–19], but interdisciplinary proposals have been implemented within general university education [20,21], and specifically within teacher education [22–25]. However, these proposals are not enough if we consider that in many education systems the school curriculum is compartmentalised in unrelated subjects. This division of the curriculum makes it difficult to include an interdisciplinary approach when it comes to teacher education [26]. This limitation affects the Spanish education system in particular, which is the setting for the educational innovation project presented in this paper.

Spanish education legislation [27] describes the skills profile for primary school teachers and determines the need for them to understand the interdisciplinary relationship between the curriculum areas at this stage, as well as design, plan and evaluate teaching and learning processes jointly with other teachers and professionals. However, teacher education in Spain involves four years of university studies (European Degree) and is strongly regulated by the Ministry of Education at a national level. This regulation involves a mandatory selection of subjects, content and competences in which the knowledge is partial and fragmented. This break down of the knowledge in the teacher education programme is evident, not only because of the large number of subjects related to the specific areas of teaching (for example, Mathematics Teaching, Social Sciences Teaching, Experimental Sciences Teaching, Physical Education Teaching), but also because these subjects are taught in different academic years which makes it hard to design interdisciplinary projects which link one activity to different areas of knowledge.

With this approach, there is a risk of creating a perception that knowledge, and the way in which it is transferred, is compartmentalised in unrelated subjects. It is not worth pretending that preservice teachers, who in general have received conventional monodisciplinary instruction, would promote interdisciplinary education in their classrooms. Therefore, Borromeo [7] insists "interdisciplinary learning and teaching require, on the one hand, well-prepared teachers, and on the other hand, adequate teaching materials for every-day lessons in school" (p. 259). Various authors state the need to provide examples that persuade, motivate and guide teachers to introduce and design interdisciplinary activities for their students [9,17,28,29].

Furthermore, the debate on the importance of interdisciplinarity and its role in society has led to the implementation of different research projects relating to improved teacher education [23,30,31]. Many of these studies are related to STEM (Science, Technology, Engineering and Mathematics) projects, which have been proliferated by the huge interest that international education policies have in preparing students for an advanced society, from a scientific and technological point of view. In these interdisciplinary projects in which active methodologies such as Project Based Learning (PBL) are the common thread, Mathematics is combined with other subjects for distinct purposes: (a) to improve Mathematics learning [18,32–34]; (b) to improve learning of the other subject [16,19] or (c) to achieve a truly integrated approach [13–15,17,24,35,36].

However, various authors reference the lack of empirical studies and emphasize the need for more studies that analyse the effect of the integrated approach on the students' learning results [37–41]. As a result, recent studies [29,42] warn that interdisciplinarity in Mathematics education, as an area of research, is still relatively unchartered territory.

The work we are presenting, based on teacher education in Spain, aims to address the aforementioned education problem with the purpose of: (a) creating an Educational Innovation Project which serves as an interdisciplinary model for teacher education and (b) evaluating how it affects the development of teaching skills amongst the preservice teachers.

Furthermore, the project was implemented with a group of primary school children so that the student teachers could experiment with innovation and evaluate its impact on the pupils' learning. Therefore, a second study was designed to evaluate the effectiveness of the Educational Innovation Project. This second study, which involved a collaboration with a school, made it possible for the preservice teachers to replicate the activity in a real learning environment with primary school children.

This way, two parallel and interrelated studies were carried out: Study 1 with preservice teachers and Study 2 with primary school children. The two studies have their own objectives and methodologies. To give them the importance they deserve, and to ensure that the specific objectives, results and discussion of each of these can be read in a linear manner, each study is presented separately. However, in the conclusion they are discussed together as the two studies are connected by the underlying interdependent relationship.

2. Educational Innovation Project

The new social, cultural, technological and production contexts require high quality and innovative education that prepares preservice teachers to lead a type of teaching that has an interdisciplinary and skills-based approach at its core. Basic skills require the incorporation of fundamental knowledge that represents the essence of competence [3], which is why we link the skills focus with interdisciplinarity, as they are both aspects of innovation that promote teaching and learning processes.

As previously mentioned, increasingly, there is a need for preservice teacher education to incorporate interdisciplinary learning that enables teachers to consolidate the skills and knowledge that are acquired during the teacher education curriculum. Acquiring teaching skills that interconnect learning entails a better quality of education for teachers, providing them training on teaching methodologies which they can subsequently apply to their lessons. However, as the school curriculum in many education systems is compartmentalised in unrelated subjects, in general the student teachers have received monodisciplinary instruction and this is a barrier when it comes to promoting an interdisciplinary focus in their classrooms.

This project, based on teacher education in Spain, aims to address this education problem and initially arose with the intention of creating an Educational Innovation Project which serves as an interdisciplinary model for teacher education. Therefore, the aim is to cover the first of the two important gaps that were identified in the introduction: the lack of interdisciplinary projects carried out for teacher education.

As a result, in order for the student teachers to improve their teaching skills, an Educational Innovation Project was carried out involving three Teacher Education subjects so that the preservice teachers could experience how an interdisciplinary project is implemented. The three subjects involved were Social Sciences Teaching, Mathematics Teaching and Educational Innovation.

The project involved the design and implementation of interdisciplinary activities using the National Archaeological Museum (NAM) as an educational resource, in which the preservice teachers could apply what they had learned in different subjects and thus practice the teaching skills required for such activity. Furthermore, the Innovation Project covers the need to promote collaborative work within the faculty [2,43–46], and to better understand one of the determining factors for teacher education: teacher's self-efficacy [47].

2.1. Design of the Educational Innovation Project

This Interdisciplinary (ID) Educational Innovation Project, carried out with teacher education students, has been possible thanks to the three subjects being taught to the same group of students in the same academic term.

The Educational Innovation subject shares the same timetable as Mathematics Teaching and Social Sciences Teaching. This meant that during the 2017−18 academic year, a pilot project could be carried out with 28 students. This pilot exposed the complexity facing preservice teachers with regards to breaking down the artificial barriers imposed by the subject. Furthermore, the need to create models so that students have the opportunity to experience interdisciplinary proposals was also identified. With this in mind as part of the Innovation Project, for the 2018−19 academic year students have had the opportunity to first experience and then design a Project Based Learning (PBL). The PBL involved carrying out interdisciplinary Mathematics and Social Sciences activities at the National Archaeological Museum (NAM) in Madrid, the main museum in Spain dedicated to archaeology and an international benchmark with huge prestige in its field.

This is a state institution whose aim is to offer "an accurate, attractive, interesting and critical interpretation of the objects that belonged to the different cultures (...) in the firm belief that a knowledge of this history can shed light on society as we know it today" [48].

Mathematics and Social Sciences are two subjects in the primary curriculum of any education system. Both of these belong to two epistemological blocks that have traditionally been known as Sciences and Humanities. This dichotomy has led to teachers carrying out teaching activity that promotes practices in the classroom that are far removed from the new skills-based approach required by the European Higher Education Area (EHEA).

To show students that the world is not compartmentalised by subjects and that Mathematics is closely linked to the physical and social world, Mathematics education experts [49–51] highlight the need to present Mathematics knowledge in relation to the world and other disciplines. Therefore, History, which is seen as a school subject, should not be approached as a body of complete knowledge but rather as knowledge under construction [52].

The experience presented does not require an integrated Mathematics and Social Sciences curriculum; rather it advocates the need to present Mathematics from a cultural perspective [53] and approach Social Sciences from a social and scientific perspective. Showing what makes Mathematics a universal subject, and an unquestionable part of all school curriculums, is precisely the activity that has been shared by all cultures through history.

The National Archaeological Museum was used as educational resource as museums are privileged spaces that address different topics [54–59], they enable knowledge to be shared and therefore offer a source of inspiration for interdisciplinary and multidisciplinary proposals which involve both History [59,60] and Mathematics [33]. Numerous studies highlight the important role that museums have as cultural spaces and learning communities [46,54,55,57,58,61,62], both from a student's perspective [57–59,63,64], as well as a teacher's perspective [56,65].

Furthermore, interdisciplinary project practice was included in the teacher education (role-play at the NAM, simulating the role of students and future teachers), so that the preservice teachers had the opportunity to experience the difficulties of performing the dual role of student and teacher [66]. As a result, when they work as teachers in the future, they will be in a privileged position to be able to identify these problems and make useful decisions to help overcome them [67].

2.2. Educational Innovation Project Timeline

The Innovation Project was carried out between September and November 2018. In total, 26 preservice teachers took part who had the challenge of designing a PBL interdisciplinary proposal that include Mathematics content based on a specific piece in the NAM, with criteria that allowed it to be classified as an educational innovation project.

The project timeline (Table 1) starts with a joint session in which teachers of the three subjects involved explained the project framework and objectives. The work plan that would be followed was also agreed. Seven teams were created based on the students' personal relationships to ensure that they worked well together, and the relationships that were established between the team members were therefore much deeper at an emotional level [68]. Each Group was randomly assigned a historic topic, taking into account the different civilisations covered in Primary Education and the distribution of rooms in the NAM (Prehistory, Protohistory, Greece, Roman Hispania, Medieval World: Al-Andalus and Christian Kingdoms, and Modern Era).

Table 1. Interdisciplinary educational innovation project - Timeline.

2018–2019 Academic Year	Sessions	Subjects Involved [1]	Task [2]	Final Result
Sept.	1 (50 min)	EI, MT & SST	Present the interdisciplinary Educational Innovation Project.	Work plan and team structure.
Sept.–Oct.	4 (400 min)	MT & SST	Create PBL interdisciplinary integrated curriculum workshops carried out in the NAM.	Experience of an interdisciplinary teaching model.
Oct.	2 (100 min)	EI	Create a rubric for evaluating the PBLs that should be designed and presented to their fellow students in the Museum.	Rubric for evaluating the PBL designed by each group and its implementation in the NAM.
1st–15th Nov.	Group work outside of the teaching timetable.		Design of an interdisciplinary PBL between Mathematics and Social Sciences.	PBL implemented in the NAM.
21st Nov.	6 (100 min)	EI, MT & SST	Role-play in the NAM (playing the role of future teachers).	Self-assessment and co-assessment of the proposals using the rubrics.
5 h Dec.	1 (50 min)	EI, MT & SST	Discuss learning that has taken place during the whole project.	Focus Group and rating the PBLs.

[1] EI = Educational Innovation; MT = Mathematics Teaching; SST = Social Sciences Teaching. [2] PBL = Project Based Learning; NAM = National Archaeological Museum.

During September and October, four sessions were dedicated to creating a PBL consisting of a series of interdisciplinary workshops, incorporating Social Sciences and Mathematics curriculum content similar to what the students would have to subsequently design for their proposals. During the first fortnight in November, each group designed a PBL based on the historic era they had been assigned. Once each group had designed their project, they implemented it at the Archaeological Museum, sharing it with their fellow students by playing the role of a teacher in a role-play consisting of two 20-min sessions per team.

For the final rating of each group, both the design of the PBL as well as its implementation in the NAM was considered, with a weighting of 70% and 30% respectively. Each group carried out their own self-assessment of their work and a joint assessment of the other groups' performance using a rubric created as part of the Educational Innovation subject. The rubric for evaluating each group's performance and achievement of various teaching skills involved different aspects such as: (a) the relationship between the proposed challenges, the objectives that were set and the content that was selected; (b) the educational suitability of the proposed activity; (c) the grounds for justifying that it was an educational innovation project; (d) exhibition resources, creativity, use of the Museum's resources and spaces and (e) the group members' participation and commitment. This information was shared in a joint session, involving the three teachers and all the students who took part. In this joint session it was also agreed to prioritise the quality of the innovation experience that was offered to the primary school children, which is why a random selection of PBLs to be replicated with the children at the NAM was not used. Therefore, the scores obtained by the seven groups in the joint assessment sessions led to the selection of the groups of students who then replicated their proposal with primary school children in the Archaeological Museum. Based on their quality, PBLs which were based on the following historic periods were chosen: Prehistory, Roman Hispania and Medieval World Christian Kingdoms.

2.3. Evaluation of the Educational Innovation Project

As well as creating an Educational Innovation Project which serves as an interdisciplinary model for teacher education, this project has as additional key objective of addressing the second important gap that was identified in the introduction related to the lack of empirical studies that analyse the effect of interdisciplinary proposals on students' learning.

Educational innovation is understood as a set of changes, that are introduced into teaching practices in a deliberate and structured manner, and which are consistent with the knowledge from different subject areas in the education field [10,11]. As we have seen, teachers' education and their professional development now require innovative approaches that enable them to successfully navigate the complex contexts in which they carry out their teaching activity. To achieve this, the different stages of education must be reconsidered: from establishing practical skills and abilities during teacher education to the renewal and development of expert skills that come from a period of professional maturity [69]. Therefore, the link between universities and schools is essential: moving towards educational innovation and transformation involves building bridges between the two institutions. In addition, it is important to verify the effects that educational innovation has on the students' learning, and we also wanted this to be an innovation learning for the student teachers. The project was implemented with a group of primary school children so that the student teachers could experience the innovation and the evaluation of the innovation's impact on the pupils' learning.

In order to evaluate the Innovation Project's effectiveness, two aspects were primarily considered: (a) the development of preservice teachers' skills, and (b) the children's Mathematics and Social Sciences learning. Thus, two parallel studies (Table 2) were carried out: Study 1 with preservice teachers and Study 2 with primary school children.

Table 2. Timeline for information gathering process.

Sample	Academic Year 2018–2019	Task [1]
Study 1 with preservice teachers	Sep. 5th Dec.	1. Pre-test measurement of variables. 2. Selection of the best PBL projects. 3. Creation of Test and Control Groups.
	6th–17th Dec.	Adjustments to the PBLs for primary school children.
	18th Dec.	Implementation the PBL with children at the Museum.
	19th Dec.	Post-test measurement of the variables and Focus Group
Study 2 with primary school children	Nov.	Contact with the school to propose the collaboration.
	3rd–10th Dec.	Design of the Control Group and Test Group by the school.
	14th Dec.	Pre-test measurement of variables.
	18th Dec.	Visit to the Museum to implement PBL.
	19th Dec.	Post-test measurement of variables.

[1] PBL = Project Based Learning.

In both cases, the studies have a quasi-experimental design, non-equivalent Control Groups and pre/post-test measurement. As previously mentioned, the two studies are interrelated and have been carried out in parallel, but they have their own objectives and methodologies. To give them the importance they deserve, and to ensure that the specific objectives, results and discussion of each of these can be read in a linear manner, each study is presented separately, as just having one structure that merges both studies would make it difficult to interpret the results. However, in the conclusion they are discussed together as the two studies are connected by the underlying interdependent relationship.

3. Method

3.1. Study 1 with Preservice Teachers

This study which was carried out amongst teacher education students will enable the effects of the aforementioned Interdisciplinary Educational Innovation Project to be evaluated, taking into account the development of the preservice teachers' skills.

3.1.1. Participants

This study was carried out amongst all of the students at the Spanish university who were in the third year of their studies during the 2018−2019 academic year. Twenty-six students participated in this study, of which 22 were women (84.16%) and four were men (15.4%). They were aged between 19 and 21 (M = 20.15; SD = 0.46).

The teachers who led the ID Educational Innovation Project considered that the experience-based opportunity using the NAM as a learning resource was so relevant, that none of the preservice teachers should miss out on it. It was therefore decided to prioritise the students' education over controlling the variables in the design of the study. The 26 student teachers were divided into two groups: the Test Group (TG) that would carry out the activity with the primary school children at the NAM and the Control Group (CG) who did not take part in the activity. Therefore, this did not involve a proper Control Group, as it was not equivalent to the Test Group because the selection was not random; rather it was based on the scores obtained in the ID Educational Innovation Project, as indicated in part 2. As a result, the Test Group was formed of 15 students: 11 that formed part of the three selected PBLs (4 from Prehistory, 3 from Roman Hispania and 4 from Christian Kingdoms) and the 4 students from the Al-Andalus group, which was in fourth place in the selection process. These were included in the activity with the primary school children in order to improve the logistics and transitions of the NAM halls.

The final distribution of the Control and Test Groups in Study 1 with preservice teachers was as follows: the TG was made up of 15 students between the ages of 20 and 21 (M = 20.27; SD = 0.46), 4 men (26.7%) and 11 women (73.34%); and the CG was made up of 11 students, all of whom were women aged between 19 and 21 (M = 20; SD = 0.45). As explained in Section 2, the fact that the working groups for designing the different PBLs were established based on the students' personal relationships, meant that the groups were not equivalent in terms of gender, as the four boys chose to work together in the Christian Kingdom project.

3.1.2. Variables and Tools

The preservice teachers completed two questionnaires; one pre-test prior to the activity with children at the Museum and one post-test following this activity.

In order to develop the questionnaire, the Spanish educational legislation [27] was checked. This establishes the requirements for verifying official university degrees which prepare people to become primary school teachers, and was used as the basic rules for designing the teacher education study plan at the University.

In this legislation, as well as others, the following objectives are established to facilitate the teaching, innovation and research skills acquired by the teachers: (a) understand the body of knowledge for the areas of the curriculum and the interdisciplinary relationship between them, (b) design, plan and evaluate teaching and learning processes in collaboration with other teachers, (c) reflect on classroom practices to innovate and improve teaching tasks, and (d) acquire skills and abilities for autonomous and collaborative learning, and promote this amongst students.

In order to set specific dimensions for the key teaching skills variable, a process to operationalise the variable took place, taking into account the results of the pilot in the 2017–18 academic year, as well as the objectives and skills in the government's regulatory order [27]. This resulted in the dimension-based structure that appears in Table 3.

Table 3. Dimensions of the principle teaching skill variable, from Study 1.

Dimensions	Description
Knowledge integration	To be capable of establishing links between the contents of different subjects in any of its dimensions.
Teamwork	Working in a team, to create a common project, with active participation from all members.
Interdisciplinary Teacher Education	To create a teaching profile that is capable of designing, organising and implementing learning proposals in the use of interdisciplinary activities.
Assessment of a teacher's role as a manager of interdisciplinary activities	To identify the management and organisation teaching functions that are involved in interdisciplinary activities.

In addition to the teaching skills variable, information was also collected from the preservice teachers regarding three secondary aspects which will form the secondary variables for study 1: (a) the assessment of museums as educational resources that facilitate an interdisciplinary experience, (b) the perception of the activity's potential for children's learning, and (c) the self-efficacy of their teaching skills for carrying out this type of activity with primary school children in the future.

A questionnaire was created to measure these variables. This was made up of 16 items with a Likert scale (1–10) and was used for both the pre-test as well as the post-test. In Table 4 examples of some items can be seen.

Table 4. Examples of items in the questionnaire in Study 1.

Type of Question	Example Questions
To what extent can you	design activities for a Primary Education class, incorporating knowledge of various subjects?
To what extent do you feel capable of	replicating this workshop or other similar ones, with primary school children?
I believe these types of activities	enable children to learn more about Mathematics/Social Sciences.
I think it has been rewarding to	trial a teaching-learning process in the museum.

3.1.3. Data Analysis

Data analysis was performed for both the principle variable (teaching skills) as well as the secondary variables, so that the scores for the Test Group and the Control Group obtained before and after the ID Educational Innovation Project could be compared (Table S1: Study 1 data collection).

Two types of quantitative analysis were carried out. Firstly, a descriptive analysis of the mean (M) and standard deviation (SD) of the Test and Control Groups for the pre/post-test measurement. Secondly, mixed variance analysis (ANOVA) for two factors, intersubject (TG/CG) and intrasubject (Pre-test/Post-test), using repeated measurements. This enables us to compare the differences between both groups (TG/CG) and between the two pre/post treatments, and also compare whether the evolution between the measurements is different for the Test and Control Groups. These analyses meant that the main effect of each factor could be confirmed, as well as the effect of the interaction between both factors. A level of significance of $p < 0.05$ was established. The IBM program SPSS_v26 was used.

Furthermore, a Focus Group facilitated by the research teachers was used to collect qualitative data.

3.1.4. Results

The principle research variable, Teaching Skills, was analysed based on its four dimensions: (a) Knowledge integration, (b) Teamwork, (c) Interdisciplinary teacher education, and (d) Assessment of a teacher's role as a manager of interdisciplinary activities.

Table 5 summarises the descriptive data for the different groups and the results for the variable's four dimensions (the minimum and maximum possible values for each measure are shown in brackets), and Table 6 shows the results of the variance analysis (ANOVA) obtained for the four dimensions of the study's principle variable.

Table 5. Descriptive statistics for the Teaching Skills variable in Study 1.

Dimension	Factor		M	SD
	Intra [1]	Inter [2]		
Knowledge integration	Pretest	CG	12.82	4.24
	(3–30)	TG	16.93	4.70
	Post	CG	17.73	5.27
	(3–30)	TG	19.00	3.98
Teamwork	Pre	CG	6.82	3.03
	(1–10)	TG	8.53	1.41
	Post	CG	8.00	1.48
	(1–10)	TG	8.80	1.37
Interdisciplinary teacher education	Pre	CG	22.09	5.79
	(3–30)	TG	25.36	2.44
	Post	CG	23.27	3.20
	(3–30)	TG	27.00	1.92
Teachers as interdisciplinary managers	Pre	CG	16.45	6.86
	(4–40)	TG	26.73	7.12
	Post	CG	21.27	5.37
	(4–40)	TG	29.87	4.72

[1] The minimum and maximum possible values for each measure are shown in brackets; [2] CG = Control Group (N = 11); TG = Test Group (N = 15).

Table 6. Results of the variance analysis for the Teaching Skills variable in Study 1.

Dimensions	Intrasubject Factor		Intersubject Factor		Interaction	
	F	Partial Eta2	F	Partial Eta2	F	Partial Eta2
Knowledge integration	11.91 **	0.34	3.11	0.12	1.97	0.08
Teamwork	2.89	0.11	4.28 *	0.15	1.15	0.05
ID teacher education	4.66 *	0.17	7.86 **	0.26	0.12	0.01
Teachers as ID managers	8.67 **	0.27	22.16 ***	0.48	0.39	0.02

Note: ID = Interdisciplinary; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The descriptive statistics show that, for the two dimensions of the principal variable (*Teamwork* and Interdisciplinary Teacher Education), the mean for all the groups is higher than the midpoint of their respective scales. This means that at a global level, the preservice teachers believe that they perform well in terms of teamwork (with means between M = 6.82 and M = 8.80, on a scale of 1 to 30) and state that they have received suitable interdisciplinary teacher education (with means between M = 22.09 and M = 27.00, on a scale of 3 to 30).

Moreover, the main effect of the intersubject factor was statistically significant in three of the four dimensions of the principle variable: Teamwork ($p < 0.05$), Inteirdisciplinary teacher education ($p < 0.01$) and Assessment of a teacher's role as a manager of interdisciplinary activities ($p < 0.001$). The main effect of the intrasubject factor was also statistically significant in three of the principle variable's dimensions: Knowledge integration ($p < 0.01$), Interdisciplinary teacher education ($p < 0.05$), and Assessment of a teacher's role as a manager of interdisciplinary activities ($p < 0.01$). However, no empirical evidence was found of any interaction between both factors in any of the principle variable's four dimensions.

In study 1, the three secondary variables were also considered: (a) Assessment of the museum as an educational resource; (b) Perception of the activity's potential for children's learning, and (c) Teaching self-efficacy. Tables 7 and 8 show the descriptive statistics and the results of the variance analysis (ANOVA) of the secondary variables in Study 1.

Table 7. Descriptive statistics of the secondary variables in Study 1.

Variable	Factor		M	SD
	Intra [1]	Inter [2]		
Assessment of the museum as an educational resource	Pre (3–30)	CG	18.82	4.75
		TG	23.93	2.55
	Post (3–30)	CG	21.91	3.05
		TG	25.00	2.14
Perception of the activity's potential for children's learning	Pre (1–10)	CG	5.55	2.42
		TG	8.00	1.36
	Post (1–10)	CG	7.18	0.60
		TG	8.73	1.16
Teaching self-efficacy	Pre (1–10)	CG	6.09	2.66
		TG	7.86	1.17
	Post (1–10)	CG	6.82	1.17
		TG	8.21	1.31

[1] The minimum and maximum possible values for each measure are shown in brackets; [2] CG = Control Group (N = 11); TG = Test Group (N = 15).

Table 8. Results of the variance analysis of the secondary variables in Study 1.

Variable	Intrasubject Factor		Intersubject Factor		Interaction	
	F	Partial Eta2	F	Partial Eta2	F	Partial Eta2
Assessment of the museum as an educational resource	6.58 *	0.22	18.75 ***	0.44	1.56	0.06
Perception of the activity's potential for children's learning	9.15 **	0.28	20.18 ***	0.46	1.33	0.05
Teaching self-efficacy	2.05	0.08	8.44 **	0.27	0.24	0.01

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

In the three secondary variables, the descriptive statistics (Table 7) show that the mean for all the groups is higher than the midpoint of their respective scales. This is especially the case for the first and third secondary variables, meaning that overall, the preservice teachers believe that museums are valuable educational resources for teaching (with means between M = 18.82 and M = 25.00, on a scale of 3 to 30) and that they have a high level of teaching self-efficacy (with means between M = 6.09 and M = 8.21, on a scale of 1 to 10). Furthermore, if we examine the post-test measurements for the Perception of the activity's potential for children's learning secondary variable, they were M = 7.18 and SD = 0.60 for the CG and M = 8.73 and SD = 1.16 for the TG, on a scale of 1 to 10. Therefore, at the end of the process, all of the participants gave very positive scores in terms of these activities' potential to improve the children's learning.

3.1.5. Discussion

As previously mentioned, the objective of Study 1 is to validate the effectiveness of the ID Educational Innovation Project for developing preservice teachers' skills. To discuss the results obtained in this study, it is important to take into account the characteristics that make this study slightly peculiar, as they are relevant to all of the limitations that have been identified.

In general, the results that were obtained demonstrate statistically significant differences between the measurements before and after the activity took place, in three of the four dimensions for the principal teaching skill variable and two of the three of the study's secondary variables.

All of the preservice teachers have improved their: (a) knowledge integration; (b) interdisciplinary teacher education; (c) assessment of a teacher's role as a manager of interdisciplinary activities; (d) assessment of the museum as an educational resource; and (e) the perception of the activity's potential for primary school children's learning. However, there has not been a significant global change in the principle variable's Teamwork dimension or the Teaching self-efficacy secondary variable.

The following testimonials from preservice teachers were captured in the Focus Group facilitated by the three teachers, which took place in the Interdisciplinary Educational Innovation Project evaluation session (Table 1). These testimonials highlight that simply taking part in the experience has enabled them to improve their perception of their own efficacy and they are able to imagine applying this successfully. They also show the impact that people's experiences have on efficacy [47,66], although in this case there is insufficient empirical evidence to prove this.

We have seen another teaching method which is different to the traditional classroom style. We have seen different ways of working other than using textbooks. The best thing has been practicing what we will be teaching. I think I will be capable of applying these types of activities to my classes in the future (Student 2).

This project has given me the tools to create a PBL as well different and original activities which are so crucial to ensuring we are innovative as future teachers. I have enjoyed practicing interdisciplinarity, seeing how enriching it can be and feeling that it is possible (Student 6).

I have been conscious of the work involved in preparing interdisciplinary activities. You have to take into account the context, manage the time you have and manage your emotions! you have to plan everything well. I have enjoyed seeing how everything we learned in the three subjects, and everything we prepared, can be applied to primary school children there's a real-life application for what we do at the university (Student 12).

This project has enabled me to cover Mathematics and Social Sciences content from a totally different perspective. Having carried out this activity in the Archaeological Museum, I have a more open mind in terms of seeing educational resources as more than just textbooks. I think I would be able to do something similar in the future when I am a teacher (Student 19).

These testimonials also show the alignment between the qualitative information obtained and the quantitative data that was previously analysed. We can see that the student teachers indicate that, thanks to this project, they have acquired new skills and improved their overall teaching skills. For example, they feel more capable of (a) establishing links between the contents of different subjects in any of its dimensions (Students 12 and 19); (b) designing, organising and implementing learning proposals in the use of interdisciplinary activities (Students 2 and 6); (c) identifying the management and organisation of teaching functions that are involved in interdisciplinary activities (Student 12); (d) recognising and appreciating the education potential of museums as learning agents (Student 19); and (e) recognising and appreciating the education potential of educational innovation (Students 2, 6, 12 and 19). Some of the testimonials (Student 2 and 19) also show a certain sense of relief from discovering that these types of projects liberate teachers from a teaching style centred on textbooks [70].

These results, which are in line with those obtained in other studies [12,22] confirm that the inclusion of different subjects in a joint project offers preservice teachers a reference framework for interdisciplinary work. Furthermore, it can be seen that when student teachers design and implement a PBL, they improve their teaching skills in general, and especially their teaching skills for interdisciplinary work. Similar results were found in other studies [23,66]. They also demonstrate that the use of the National Archaeological Museum as an educational resource improves students' involvement in their own learning process. This is aligned to the results obtained by other studies [46,55,56,65], who argue that museums are valuable educational resources for teachers, as they improve motivation, enrich the educational offering and optimise teachers' work. However, the results obtained in relation to teamwork and the self-efficacy are contrary to those reached by Denigri [71], who argues that interdisciplinary experiences lead to greater expressions of self-efficacy, in both educational tasks as well as teamwork and the ability to innovate. With regards to self-efficacy, the results that were obtained are different to those from other studies [16,21,25,72,73], which demonstrate the improvements achieved by teachers and preservice teachers in terms of their skills. For this study, the data shows that all the students started with a high level of self-efficacy and they have all improved this variable, although not in a significant manner.

These results, which equally affect all of the students who participated in the study, could be determined by the fact that the teachers who led the Innovation Project echoed the authors by demanding that students should be given opportunities to experience and implement integrated curriculums [7,9,17,28,29], and made the decision to prioritise preservice teachers' education ahead of controlling unknown variables in the study's design. As a result, students were not initially assigned to the CG or the TG. Due to the importance of experience in their learning, all of the students (without exception) carried out an Interdisciplinary Project using the Archaeological Museum as an educational resource. With regards to the results obtained for the *Teamwork* variable, it could be the case that for the design of the PBLs, students form groups based on their similar approaches to collaboration, as this would guarantee deeper relationships at an emotional level [68].

The other unique feature of this project that has affected the study's results is linked to the setup of the Test and Control Groups. This involved a collaboration with a school so that preservice teachers could replicate the activity in a real-life learning environment with children at the Archaeological Museum. The desire to achieve excellence in the educational activity the preservice teachers carried out with children, meant that the selection of the Test Group was not random; rather based on the scores obtained in the Interdisciplinary Educational Innovation Project. Because of this decision, in Study 1, empirical evidence has been found in favour of the Test Group. This shows a significant difference in the scores across all the variables that were analysed, with the exception of *Knowledge Integration*. Although these results are clearly an outcome of the non-random way in which the subjects were assigned to the research groups, they demonstrate that carrying out collaborative teacher education projects between universities and schools improves skills related to interdisciplinary work. Furthermore, as stated by Tytler et al. [34], it is proven that preservice teachers' self-efficacy improves when they are able to design and apply a PBL with children in a real-life learning environment.

Finally, it is worth mentioning that there is no evidence that suggests the activity with children in the Museum enabled the Test Group to significantly improve more than the Control Group in regards to any of the variables that were analysed.

Despite the limitations, in general we have seen that the preservice teachers feel more competent when it comes to designing and implementing interdisciplinary projects. These results suggest that the Interdisciplinary Educational Innovation Project carried out, has not only served to provide an interdisciplinary model for teacher education, but also to support the development of the student teachers' teaching skills, and this confirms the need to continue developing models for improving the quality of teacher education.

Limitations

The most obvious limitation from the discussion of the results is related to how the Test and Control Groups were formed in the study that was carried out. As it is previously indicated, the groups are neither homogenous nor equivalent. The university wanted to give all their students the opportunity to experience the interdisciplinary activity in the Archaeological Museum. Putting the education ahead of controlling the external variables in the study's design has made it difficult to obtain the desired results in terms of greater effectiveness of the intervention in the Test Group compared to the Control Group.

We have also faced other challenges regarding organisation. In Spain, the lack of communal spaces and shared time in the timetables have been an obstacle for finding the right moments to hold the necessary meetings to prepare and coordinate activities between the three professors of the three subjects involved in this project; even more so given the marked face-to-face nature of Spanish universities. It was not easy to ensure the professors could be together in the sessions requiring the involvement of two or three subjects (see the timeline in Table 1). In order for the preservice teachers (accompanied by the three professors) to be able to present the PBLs they had designed at the National Archaeological Museum, a number of changes and adjustments had to be made to the timetables. This affected other professors and groups of students, none of whom were involved in this project. These co-teaching sessions were a key element for showing the preservice teachers how to implement an interdisciplinary project, and were able to take place thanks to the availability of university professors, the rest of the teaching team's understanding, and the management team's involvement.

Finally, another area that would need improvement in future studies relates to the evaluation of Assessment of Learning. This is a key pillar for educational processes, making it even more relevant when it is applied to teacher education. In the case of teacher education, the three professors involved in the Interdisciplinary Project found it easy to agree on the rubric indicators for evaluating the quality of the PBLs designed by the preservice teachers and implemented in the Archaeological Museum. However, the need to combine the criteria that would result in the feedback given to students was not considered, leading to a discrepancy in the feedback given by the different areas involved in the project.

3.2. Study 2 with Primary School Children

This second study was carried out with primary school children at a public school with the intention of evaluating the effectiveness of an Interdisciplinary Educational Innovation Project in preservice teacher education. Thanks to this study, a sample of preservice teachers (the Test Group in Study 1) had the opportunity to replicate the PBLs they had designed in a real-life learning environment with children at the National Archaeological Museum.

3.2.1. Participants

A Public School in the municipality of Torrelodones, Madrid, was selected by convenience sampling to participate in this stage of the research. This school was chosen in particular, as it had already collaborated with the university on the professional work experience that Spanish student teachers have to carry out during their studies. A decision was made to work with students aged between 11–12, in the final year of primary school in the Spanish school system (Year 7), to ensure that the civilisations that would be covered in the Archaeological Museum, as part of the proposed interdisciplinary activities, had either already been studied in previous years or would be covered throughout the 2018–2019 academic year. Following the protocol established for special educational activities, the School received approval from the School Board (the governing body made up of representatives from the educational community) so it could be involved, facilitate the students' participation and get support from their families.

During the 2018–19 academic year, the School had three groups (A, B and C) in Year 7 with a total of 58 students: 33 were boys (56.9%), 24 were girls (41.38%) and one (1.72%) did not indicate their gender. Following the researchers' explanations, the School understood the need to use the Control Group and Test Group to prove the effect the activity had on the children. However, the school reserved the right to randomly assign the Test and Control Groups and insisted that each had a proportion of students from the three classes (A, B and C) in Year 7.

The random assignment of groups was carried out by the School Board to ensure the Test and Control Groups were as balanced as possible, taking into account the aforementioned criteria. Thirty-three students (57%) were assigned to the TG, of which 25 were male (75.8%) and 8 were female (24.2%), and 25 students (43%) were assigned to the CG, of which 8 were boys (32%), 16 were girls (64%) and 1 (4%) did not indicate their gender. The TG included 12 students from group A, 11 from group B and 10 from group C, whilst the CG included 8 from group A, 7 from group B and 10 from group C. Of the 58 students, 7 had repeated a course (12.1%); 5 were not Spanish nationals (8.6%) and 3 had special educational needs (5.2%). The TG included 5 students who had repeated a course; 3 who were not Spanish nationals and 3 students with educational needs (attention deficit disorder, attention deficit hyperactivity disorder or motor disorders).

Information was obtained from both groups regarding their previous experience with visiting museums. In the TG, 59% of students had visited a Natural Sciences museum, 70% an Art museum, 70% a History museum and 33% had visited the National Archaeological Museum. In the CG, 76% had visited a Natural Sciences museum, 64% an Art museum, 64% a History museum and 18% had visited the National Archaeological Museum.

3.2.2. Variables and Tools

The three variables that were analysed (both pre and post-test) in the total group of 58 children from the school were: (a) the children's perception of the museum as a place for learning, (b) knowledge of Social Sciences for the Prehistory, Roman Hispania and Christian Kingdoms, and (c) knowledge of Mathematics relating to challenges in the PBLs on roman numerals, symmetry, polygons and geometric shapes. Furthermore, the students in the TG were asked about their satisfaction with the activity carried out in the NAM.

The tools used to collect information on the subject knowledge included two multiple-choice tests. Two parallel tests of similar difficulty, structure and size were designed for each subject. One of these was applied to the pre-test and the other to the post-test in order to control the effect of the possible learning in the first stage. Previous experiences visiting museums were evaluated using a questionnaire with four questions. Perceptions on museums as well as students' satisfaction were measured by a Likert scale (0–10) of eight and nine items respectively.

3.2.3. Data Analysis

Data analysis was performed to compare the Test Group and Control Group scores that were obtained before and after the experience in the museum. The objective of this analysis was to understand whether the effect of the intervention had a positive impact on their learning and perception of museums (Table S2: Study 2 data collection).

Two types of quantitative analysis were carried out: (1) descriptive from the mean (M) and standard deviation (SD) of the Test and Control Groups; (2) mixed variance analysis (ANOVA) for two factors, intersubject (TG/CG) and intrasubject (Pre-test/Post-test), using repeated measurements. This analysis made it possible to confirm the main effect of each factor, as well the effect of interaction between both factors in each of the variables.

A level of significance of $p < 05$ was established. The IBM program SPSS_v26 was used.

3.2.4. Results

The descriptive statistics (Table 9) show that in general, everyone has a positive perception of museums as a place for learning (with a mean between M = 53.13 and M = 59.10, on a scale of 0 to 80) and the TG students have a positive view of their experience at the NAM (M = 57.67, SD = 12.65, on a scale of 0 to 70) with regards to their learning.

The results of both the Mathematics and Social Sciences knowledge tests were poor; on a scale of 0 to 9, all of the averages were less than 5 with the exception of the post-test in the TG which was 5.7 and 5.2 for Social Sciences and Mathematics respectively.

As can be seen in Table 10, the principle effect of the intrasubject factor was statistically significant in the three variables analysed: Perception of museums as a place for learning ($p < 0.05$), and knowledge of both Social Sciences ($p < 0.05$), and Mathematics ($p < 0.05$).

Table 9. Descriptive statistics corresponding to variables in Study 2.

Variables	Factor		M	SD
	Intra [1]	Inter [2]		
Perception of museums as places to learn	Pre (0–80)	CG	53.13	10.85
		TG	55.74	11.42
	Post (0–80)	CG	55.22	12.22
		TG	59.10	8.33
Knowledge of Social Sciences	Pre (0–9)	CG	4.28	1.14
		TG	4.47	1.63
	Post (0–9)	CG	4.72	1.84
		TG	5.69	2.01
Knowledge of Mathematics	Pre (0–9)	CG	3.64	1.63
		TG	3.97	1.49
	Post (0–9)	CG	4.36	1.63
		TG	5.16	1.85
Satisfaction with the activity in the museum	Post (0–70)	TG	57.67	12.65

[1] The minimum and maximum possible values for each measure are shown in brackets; [2] CG = Control Group (N = 25); TG = Test Group (N = 33).

Table 10. Results of the variance analysis corresponding to variables in Study 2.

Variable	Intrasubject Factor		Intersubject Factor		Interaction	
	F	Partial Eta2	F	Partial Eta2	F	Partial Eta2
Perception of museums as places to learn	4.45 *	0.08	1.51	0.03	0.24	0.01
Knowledge of Social Sciences	7.60 *	0.12	2.88	0.05	1.67	0.03
Knowledge of Mathematics	11.80 *	0.18	2.64	0.05	0.72	0.01

Note: * $p < 0.05$.

However, the analysis of the scores for the principle effect of the intersubject factor was not significant in any of the three variables in Study 2.

No empirical evidence was found in either of them regarding the existence of interaction between both factors.

3.2.5. Discussion

The study designed to evaluate the effectiveness of the Educational Innovation Project involved a collaboration between the university and the school to enable preservice teachers to carry out activities in a real-life learning environment with children at the NAM. As previously mentioned, the objective of Study 2 was to evaluate the learning improvements for Mathematics and Social Sciences amongst primary school children following the activity that took place, as well as their appreciation of museums as places for learning.

If we consider the results obtained from the students who formed part of the Test Group, they coincide with those from other studies relating to museum-based interventions [57,59], which confirm that the primary school children who were involved in the interdisciplinary experience had a positive perception of museums as places for learning.

However, when we consider the study as a whole, the results obtained are unexpected. Based on similar situations in the CG and the TG, the results enable any statistically significant changes to be identified between the pre-test and post-test averages across the three variables that were studied. All of the children who participated in Study 2 have improved both their perception of museums as places for learning, as well as their knowledge of Social Sciences and Mathematics. However, none of the comparisons have provided any significant evidence to confirm whether the interdisciplinary activity carried out in the Archaeological Museum had more of an impact, across any of the three variables, on students in the TG over the CG. Although these differences are not significant, better scores are observed for the TG. These results make it impossible to demonstrate that the interdisciplinary activity at the NAM led to significantly higher improvements in any of the study's variables. However, although other interdisciplinary projects have obtained statistically significant results that show an improvement in Mathematics performance [16,21,35], or understanding of Social Sciences content [16,59]; there are also studies carried out with primary and secondary school children related to both museum-based interventions [58], as well as interdisciplinary approaches [18] that, like this one, have had unexpected results.

Limitations

As was the case in Study 1, the specific characteristics resulting from this teaching collaboration have influenced the results of Study 2 and are a limitation in terms of the results that were obtained. At the same time, they show the changes that should be made in the future if similar studies were to take place amongst the children at the School.

One of the main limitations of this study is the fact that the control and test groups are not equivalent. The lack of collaborative culture between the university and the school for carrying out educational research means that the school is somewhat reluctant to understand the need to use a control group to prove the effects of the intervention on the children. In our case, although the school understood the need to use a Control and a Test Group, they reserved the right to define the groups and the random assignment was carried out by the School Board.

The whole group's improvement can be a result of the design used to form the Test and Control Groups. The improvements in the CG (both in terms of knowledge as well as the change in the perception of museums as places for learning) could be attributed to the contagion effect between the groups, caused by the structure suggested by the School Board, as they requested that the TG contained students from the school's three classes (A, B and C). Furthermore, the school's desire to offer all its students the same learning opportunities slowed down the activity at the Archaeological Museum. It was postponed until the school's management team could find another activity to offer students from the CG. In addition, the school's collaborative culture meant that this would be of benefit and a joint discussion session was organised for the students who carried out the interdisciplinary activity at the NAM to share their experiences with everyone else. The diverse nature of the Control and Test Groups, coupled with the collaborative learning culture that exists with the School has meant that the interdisciplinary education activity at the Archaeological Museum not only had an impact on the children who took part, but also on their fellow students who benefited from being told about the activities that were experienced. This could call into question the results of Study 2 and serves as a reminder that in the educational environment, any innovation, no matter how small, can have positive repercussions beyond just the people involved in the experience.

The fact that there is no significant evidence to prove that the activity in the Museum had more of an impact for the children in the TG could be due to the types of questionnaires used in Study 2. In order to gather information on the children's Mathematics and Social Sciences knowledge, two multiple-choice tests with single and closed responses were used. Williams et al. [29] warn that interdisciplinary studies that measure their results in a traditional manner tend to find few positive results. This can affect the study that has been carried out as Study 2 has used traditional questionnaires to measure the results of an innovative intervention, which aims to evaluate creativity and find connections between subjects.

Furthermore, these traditional questionnaires should have been designed to take into account the development of the skills involved in interdisciplinary activities. It is important to take this point into consideration when replicating the project or designing other similar ones, in order to fill the gap identified by Deneen et al. [41], and offer preservice teachers an evaluation model for learning in interdisciplinary interventions, which not only gives them the opportunity to evaluate Assessment for Learning (AfL), but also to receive training to put this into practice.

Finally, in both Study 1 and Study 2, it would have been necessary to work with bigger samples, which is somewhat complicated in studies such as this one due to the difficulties found when coordinating the three entities involved (the university, school and museum) as their own organization.

4. Conclusions

The project that has been presented in this article is based on teacher education in Spain and aims to address the claims from different authors who indicate that, although Interdisciplinary projects play an important role in the development of a student profile based on the 21st century skills [1–10], the implementation of an interdisciplinary approach is a challenge for both teachers and teacher educators [29,37–40,42]. If we also take into account that in many education systems, the school curriculum is compartmentalised in disconnected subjects, it makes it difficult to preservice teacher, who in general have received conventional monodisciplinary instruction, promote interdisciplinary education in their classrooms. Therefore, the aim of this study was to create an Educational Innovation Project, which serves an interdisciplinary model for teacher education, and to provide an empirical study which analyses its impact on learning.

Thus, an educational innovation project was carried out with preservice teachers who experienced and subsequently designed a Problem Based Learning with interdisciplinary activities including Mathematics and Social Sciences, using the National Archaeological Museum as an educational resource. Furthermore, so that the student teachers could experience the innovation, and the evaluation of this innovation on the pupils' learning, a second study which involved a collaboration with a school, was designed. This second study, meant that the preservice teachers could implement the interdisciplinary PBL projects they had designed, in a real learning environment with primary school children, as well as participate in the evaluation of the innovation project. This addresses the request from Deneen et al. [41] to offer preservice teachers an evaluation model for learning in interdisciplinary interventions, which not only gives them the opportunity learn how to carry out an evaluation of Assessment for Learning (AfL), but also to receive training to put this into practice.

Therefore, to evaluate the Innovation Project's effectiveness, the development of the preservice teachers' skills was taken into account, as well as the children's learning.

This is how both of the studies presented in this research, Study 1 with preservice teachers and Study 2 with primary school children, are connected.

This interdependence between both studies, which has meant that the design of this research has been somewhat strange, has also meant that one of its main contributions is precisely that it provides an interdisciplinary intervention model, which can be used both for teacher education and in primary schools as well.

Although we have presented the two studies separately, along with their results and limitations, we are going to resume a combined view of these both to discuss the connections that were found.

The results that were obtained are positive as there is statistically significant evidence that there have been improvements in the majority of the variables analysed in both studies. In the case of the student teachers there have been significant improvements in teaching skills for interdisciplinary work, as well as their perception of the activity's potential for primary school children's learning. In the case of the children, there have been significant improvements in the learning of Mathematics and Social Sciences. Furthermore, both groups have improved their perception of museums as educational resources.

These results are in line with those from similar studies, which found evidence that demonstrates the positive effect that interdisciplinary designs have on both preservice teachers [22,23,66] and school children's learning [12,16,21,35,59]. They all confirm the educational value of the interdisciplinary experiences, as an innovative methodology for teacher education, and justify the need to continue advancing in this field to provide preservice teachers with interdisciplinary models that can be replicated in their teaching experience.

However, unexpected results have been found in both studies. In both cases, there is no evidence that suggests the activity in the Museum enabled the Test Group to significantly improve more than the Control Group in regards to all of the variables that were analysed. These results mean it is not possible to demonstrate that the interdisciplinary activity at the NAM has produced significantly better improvements in any of the study's variables. Although we would have preferred this not to have been the case, our research is not the only one in which an interdisciplinary intervention produces unexpected results, insofar as it does not demonstrate that the Test Group students achieved significant improvements. This was also the case in the Museum-based intervention with primary school children carried out by Kavevsky, Corke and Franqkiser [58], or the curriculum integration intervention with secondary school students, carried out by Parr, Edwards and Leising [18].

Although these results were not what was hoped for, the fact that they have been the same for both studies means we must reflect on the possible causes for this, so they can be taken into account if the research is repeated in the future. In the discussions on each study, the limitations of each of these have been analysed, although in the following section we will consider these for the project as a whole. Nevertheless, although the desired effects have not been reached in the activity with the children, it would be useful to be able to carry out similar interventions in collaboration with the school. These types of projects provide opportunities to evaluate their impact on children's learning in a real-life scenario. This is one of the project's most valuable aspects as very few studies use experimental designs to prove the effectiveness of an innovative intervention; fewer still have done this in a dual manner, evaluating the effect on preservice teachers as well as primary school children.

Challenges Encountered and Proposals for Improvement

We will now present some recommendations based on the challenges we have faced during this research:

- It is important to have shared spaces available, and meeting times that enable coordination between the teachers of different subjects, in order to plan and design both the implementation as well as the evaluation of the interdisciplinary proposals in an agreed and coherent manner. Equally as important is the ability to articulate the positive effects of interdisciplinary teaching to the rest of the educational community. The researchers agree with other authors [28,59,74–76], who demand that public administrations reconsider the programs and legislate, taking into account the benefits derived from interdisciplinary work.
- The study has also shown how difficult it is to break down the artificial barriers involved in structuring a subject's study plan, especially when these types of experiences have not occurred regularly during the training. It is necessary for the study plans to be more aligned to the new learning styles required to achieve 21st century skills. The authors agree with others who claim that changes in teacher education are required at all stages, in order to achieve this [2,9,17,23,34,42,69,77]. As a result, interdisciplinary work proposals should be improved, during both preservice and in-service teacher education. This will improve teaching self-efficacy, and the teachers will therefore develop the necessary skills in order to take on the role of managing these types of activities.
- Finally, it is essential for there to be strong and effective collaboration between the university and the schools: Striving for innovation and education transformation involves building bridges between both institutions. In general, compulsory education teachers tend not to be aware of the studies carried out by universities [30]. Moreover, in the universities' study plans, teachers sometimes do not facilitate an approach to knowledge that truly defines the school [78]. However, to achieve quality, education should strengthen the collaboration between the two, putting aside the university's academic roots and the school's practical focus. Carrying out joint research projects is an ideal framework for making this happen.

As can be seen, the first two proposals would help to introduce the necessary changes required to achieve more flexible curriculums in a planned and systematic manner, thus enabling different subjects to be included in teaching. We believe that, if implemented in a deliberate and structured manner, they would help to introduce an interdisciplinary approach in teacher education, which as we have seen, would lead to an overall improvement in the quality of the education. It is also evident that these proposals are a challenge at all levels. A challenge for all of the groups involved (teachers, students, preservice teachers, management teams and public administrations) to implement the changes required across different levels (organisational, curricular, structural, economic and even attitudinal). Therefore, as urged by Williams [76], the researchers appeal "to theory, policy and practice to re-think the notion of school discipline, and to unleash the learner, teachers, and the schools from discipline" (p. 9).

It is clear that there is still a long way to go, but we disagree with Williams [76] who argues that we should be "realistic and demand the impossible" (p. 9); as being optimists, we only demand what we consider is possible to achieve, especially in the context of the Sustainable Development Goals Agenda, that claims for quality education.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/17/6748/s1, Table S1: Study 1 data collection, Table S2: Study 2 data collection.

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