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Engaging kindergarten pre-service teachers in the design and implementation of STEM lessons

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Introduction: Engaging young students in integrated STEM early on can support them to develop their competences linked to problem solving and critical thinking. Despite the importance of STEM education in younger ages, teachers still lack the skills and competences to implement STEM in their classes. The purpose of this study is to explore how pre-service kindergarten teachers (PSTs) understand STEM education, how they design lesson plans to teach STEM and how they implement STEM in their teaching.

Methods: Participants of the study were 21, 3rd, and 4th year students studying to become kindergarten teachers. The participants of the current study attended a Science Methods Course for Kindergarten which is a 36 h long course. Data collected included questionnaires, reflections, lesson plans, interviews, and classroom observations.

Results: Findings for the first research question reveal that kindergarten PSTs were not familiar with STEM education and did not have any previous experience with STEM education either as school students or during their studies at the university. Another important finding is that teachers' views on STEM education improved after the theoretical introduction to STEM, but considerable improvement and understanding of STEM education was evident after they engaged as learners in a STEM lesson specially designed for kindergarten students.

Discussion: Findings from the lesson plans designed by the PSTs showed that when working in groups PSTs designed lessons which offered integration between two subjects, mainly math and science. Finally, when implementing STEM lessons PSTs had similar difficulties as when designing lessons. Additionally, PSTs reported that they did not have support from their mentors, or their mentors did not act as role models during the implementation of their designs. What this study supports is the need for teacher preparation programs to prepare kindergarten teachers in understanding what STEM is, but also supporting them in the process of designing and implementing STEM lessons. Implications from this study include the design of a teacher training course to support PSTs during their studies and in their early career, but also include mentors as part of the training course to support them to act as positive role models.

KEYWORDS

STEM education, kindergarten, pre-school, pre-service training, teacher professional development

1 Introduction

STEM (Science Technology Engineering Mathematics) education has been the emphasis of many studies, with more recent studies agreeing on an integrated STEM approach which breaks the traditional boundaries between the different disciplines (Ortiz-Revilla et al., 2022). Integrated STEM is focusing on competency-based curriculum that will "prepare young people with required competences to live sustainable, fulfilled and healthy lives in the rapidly changing world of the 21st century" (Ng, 2019, p. 3). Despite the emphasis on integrated STEM, and breaking the boundaries between the disciplines, the very structured nature of curricula across countries, especially in the education of older students (i.e., secondary school) does not allow for that integration. The context of kindergarten (4–6 year old) is suitable to promote integrated STEM education, not only because of the flexibility of the curricula, but also because of the benefits that such a curricula can bring to younger students. By engaging in integrated STEM from a younger age students can develop their competences linked to problem solving, and further develop their questioning practices (Brenneman et al., 2009). Recent studies (i.e., Uğraş and Genç, 2018; Chen et al., 2021; Yıldırım, 2021) have focused on kindergarten teachers' views about STEM, and fewer studies on professional models for the development of STEM teaching competences for in-service teachers (i.e., Brenneman et al., 2019). However, there are limited studies examining how kindergarten pre-service teachers (PSTs) understand STEM, design STEM lessons, and implement them in action. According to Hapgood et al. (2020) there are still gaps in how to measure STEM learning, how to improve teachers' knowledge and how to design robust materials for kindergarten teaching and learning education. The limited understanding of the challenges that kindergarten PSTs face in understanding, designing, and implementing integrated STEM is considered as a gap, and by addressing this gap we can potentially support teacher training and teacher professional development programs.

Based on the aforementioned gap, the purpose of this study is to explore how pre-service kindergarten teachers (PSTs) understand STEM education, how they design lesson plans to teach STEM and how they implement STEM in their teaching. Specifically, the research questions guiding the study are the following:

R.Q.1. What are kindergarten PSTs views and knowledge of STEM education before and after engaging with integrated STEM?

R.Q.2. What difficulties do kindergarten PSTs have when designing a STEM lesson plan?

R.Q.3. What difficulties do kindergarten PSTs have when implementing a STEM lesson plan?

2 The importance of STEM education and teacher preparation

Recent initiatives in education place an emphasis on integrated STEM education (Ryu et al., 2019), which is the integration of the multiple related subjects (science, technology, engineering and mathematics). The emphasis on STEM education is linked to the need to improve students' knowledge and understanding of STEM related concepts, but also their skills and competences. It is also related to the fact that the nature of STEM blurs the lines between the disciplines (i.e., Wang et al., 2011). Changes in our society call for skills that come across the different disciplines and can potentially help the students become responsible citizens, and have the required skills to navigate the employment world when they finish school. Integrated STEM approaches which focus on skills can support students from different backgrounds and under-represented populations, including girls (Evagorou et al., 2020) even though strong evidence is still missing (Honey et al., 2014). There are different approaches in STEM education in the literature, some of which focus on a single STEM subject, and others which focus on the integration of the disciplines. One of the frameworks of quality STEM education, by Moore et al. (2014), focuses on six key elements as important: the use of authentic and motivating context; teaching which allows students to engage in engineering challenges; the space to learn from failure; include appropriate science and mathematics content; an approach that is student centered; and teaching which includes group work and communication. The Moore et al. (2014) framework is specific to integrating engineering in STEM but nevertheless is useful in identifying the pedagogical aspects that are important in integrated STEM. In the study the emphasis is on integrated STEM which is related to the integration of the different topics with an emphasis mainly on science, mathematics and technology, which requires a problem solving and inquiry-based approach (Ryu et al., 2019). In the current study engineering was not highlighted, mainly because it is not included as part of the local curricula in the kindergarten. Technology in our framework is linked with the competences highlighted in the DigComp Framework (Vuorikari et al., 2022) which include: information and data literacy, communication and collaboration, digital content creation, digital safety and problem solving. Summarizing, the STEM framework in the current study places an emphasis on a learning environment which is problem oriented, is focusing on the integrating and use of competences and knowledge from more than two disciplines (namely science, mathematics and technology) and is following the pedagogical guidelines suggested by Moore et al. (2014).

As highlighted above, the emphasis of STEM education is on developing students' competences linked with critical thinking, problem-solving, and inquiry-based learning, and supports them in understanding the connection between STEM and the real word (Labov et al., 2010; Breiner et al., 2012). Therefore, STEM education should be based on a curriculum that can "prepare young people with required competences to live sustainable, fulfilled and healthy lives in the rapidly changing world of the 21st century" (OECD, 2019, p. 3). Young kids have a natural disposition toward STEM subjects because of their natural curiosity (DeJarnette, 2018). Introducing STEM education in early years is considered important because young children ask questions and are curious to learn more about the world around them (Yıldırım, 2021). Other researchers state that important brain growth and learning takes place during early years (Catherwood, 1999) and that benefits from quality early childhood education can impact a child through their adulthood (Sylva et al., 2010) and therefore early STEM education can be critical (Campbell et al., 2018). Therefore, introducing STEM education in preschool can support students' curiosity and encourage them to learn STEM related concepts and develop skills (Yıldırım, 2018). Other researchers (Campbell et al., 2018) observed that young students' STEM experience improved their self-efficacy to learn STEM and their appreciation of STEM subjects.

STEM education should focus on developing in-service and pre-service teachers' STEM knowledge and teaching practices. Teachers should also be aware of the nature of STEM education and the complexities involved in the teaching process. One of the challenges in integrated STEM is blurring the boundaries between the different disciplines and providing a more spherical understanding of how the different fields can work together for teachers (Evagorou et al., 2020). Teacher preparation is important in order provide the necessary pedagogical guidelines to educators to enable them to understand first integrated STEM, and then to support them in their effort to design appropriate lessons and implement them in action. PSTs in secondary education are prepared on how to teach within their own field only (i.e., math, science) and are not familiar with integrated approaches (Evagorou et al., 2020). Kindergarten and primary PSTs are prepared to teach all courses of the curricula, but they are still prepared to teach the different courses separately (i.e., science, math, language). Recently, some programs have focused on preparing PSTs for integrated STEM (i.e., Ryu et al., 2019). In their study Ryu et al. (2019) designed an integrated STEM course for secondary school teachers and explored how PSTs develop integrated STEM courses and what challenges they face in developing and implementing the courses. Findings from this study support that the limited understanding by PSTs on how the subjects are linked did not allow them to integrate the subjects and they believed that if they include S, T, E, M in a way in their teaching they are doing integrated teaching. An additional finding in the same study is that PSTs lack role models and experiences of STEM activities since integrated STEM is not widely introduced in schools and therefore most of them do not have experiences either as students or as PSTs.

Other than the difficulties mentioned above, kindergarten teachers typically lack content knowledge of STEM domains and often hold negative attitudes toward STEM subjects (DeJarnette, 2018; Yıldırım, 2018). Yıldırım (2021) in their study offered an 80-h STEM training program to kindergarten teachers. The findings of this study show that kindergarten teachers understand the purpose of STEM education as supporting students to increase their creativity, problem solving, critical thinking skills and communication, and furthermore they believe that STEM can help students increase their interest in STEM. The same study by Yıldırım (2021) showed that teachers did not know how to plan a STEM lesson and had a lack of resources to support them in planning, and lack of equipment. One limitation of this study is that all views are self-reports by teachers and lesson plans were not analyzed. A similar study by DeJarnette (2018) engaged in-service teachers in professional development and explored how kindergarten teachers implement STEAM in their teaching after the professional development. The study showed that before the professional development teachers spend less time teaching the content in which they lack knowledge, but after the professional development they improved their self-efficacy but still the rate of implementation of STEAM lessons was limited. Finally, Campbell et al. (2018) explored how kindergarten educators engage preschool students in STEM. According to their findings STEM activities in preschool were presented as either mathematics or science activities and teachers' level of comfort in teaching STEM influenced how they designed the activities and some teachers mentioned that there was a "gap in their understanding about how best to integrate" (p. 23).

The findings from these studies highlight the gap in the literature when in comes to understanding PSTs difficulties in understanding and implementing STEM education with younger students, and this is what the current study aims to address.

3 Materials and methods

3.1 The context

The participants of this study were 3rd and 4th year students studying to become kindergarten teachers (specializing in 4–6-year-old students) at a private university in Cyprus. The program of study they were attending is a four-year program leading to a Bachelor in Education which covers theoretical and practical perspectives of becoming a kindergarten teacher. The program includes school practicum in kindergartens during the last 2 years of study. During the school practicum PSTs take over a classroom and are mentored by the classroom teacher and regularly observed by faculty members. The program of study does not include a STEM education course, but includes separate courses on science, math, and technology education. Engineering education is not part of the program of study as this is not included in the local kindergarten curricula. The participants of the current study attended the Science Methods Course for Kindergarten which is a 12 week-long, 3 h per week course. The course is designed to provide theoretical perspectives on teaching science to younger students, includes workshops on lesson design, and contains a practical part in which PSTs are asked to interact with younger students during a science activity in a kindergarten.

During the Fall 2021 semester in which the data for part of the study was collected, part of the course was redesigned with an emphasis on STEM education. The decision to redesign the course was based on: (a) the emphasis in research and policy to introduce STEM education in school, especially in early years (Achieve, 2013; EU STEM Coalition, 2016; European Schoolnet and Texas Instrument, 2018), and (b) the collaboration developed between the instructor of the course and two other colleagues at the Department of Education specializing on technology and math education. This collaboration led to the development of integrated STEM lesson plans that were implemented with 4–6 year old students and modified based on feedback by practicing kindergarten teachers. The integrated STEM lesson plans were used as exemplars during weeks 8–10. As part of the course, PSTs were asked to design a STEM lesson plan in groups with a duration of 4 periods of 40-min lessons, and present one of the activities in the form of microteaching to the rest of the class. The content and structure of the Science Methods Course for Kindergarten is presented in Table 1.

3.2 Participants

Participants for the first and second research questions were 21 PSTs in their third and fourth year of study, who attended the Science Methods Course for Kindergarten during the Fall 2021 semester. All participants were female. Students attending the BA in Kindergarten program are students who join the program with low grades from high-school, especially in the sciences (science, mathematics, technology), and negative attitudes toward the STEM disciplines. Furthermore, these students have experiences using technology for their own use (i.e., social media, to prepare an

TABLE 1 Structure and content of Science Methods Course.

Week	Description of content
Week 1	Introduction to science learning and the local curriculum
Week 2	Introduction to students' alternative ideas, the constructivist model of learning, and socio-cultural theories of learning in science
Week 3	Inquiry based learning in science
Week 4	Scientific and engineering practices as presented in the Next Generation Science Standards (Achieve, 2013) and connection to STEM education
Week 5	Introduction to modeling as a scientific practice (Achieve, 2013; Evagorou et al., 2020)
Week 6	Designing science lesson plans for younger students based on the local curriculum with an emphasis on students' experience and questions. Providing examples of science lesson plans for 4–6 year old students
Week 7	Introducing STEM and interdisciplinarity—theoretical perspectives of STEM education, benefits of STEM education and what research has to say
Week 8	Engaging in an integrated STEM lesson as students and reflecting on the process
Week 9	Characteristics of a STEM lesson (problem based, guided by a question, interdisciplinary, inquiry based)
Week 10	Turning a science lesson into a STEM lesson (transforming science lessons from the curriculum into a STEM lesson in their groups)
Week 11	Microteaching of the STEM lesson designed by the groups of students, interviews with groups and feedback on lesson by instructor
Week 12	Implementing STEM activities with 4–6 year old students in a kindergarten

TABLE 2 Profiles of case studies.

Pseudonym of participant	Profile
Sonia (PST 2)	High achieving student, positive evaluations in 3rd year school practicum, outgoing, social, reported positive science and math experiences from school, very good technological skills, high self-reported readiness to teach science, math and use technology
Ariana (PST 7)	Average grades in degree, positive evaluations in 3rd year school practicum, reported positive science and math experiences from school, good technological skills, average self-reported readiness to teach science, math and use technology in the classroom
Lucy (PST 9)	Average grades in degree, average evaluations in 3rd year school practicum, reported positive science and math experiences from school related to outdoor activities as part of a research program, her native language is different than the language of instruction, low self-reported readiness to teach science and math, and high self-reported readiness to use technology in the classroom

assignment) but they usually have basic technological skills. For the third research question, data were collected from three PSTs, as case studies. The decision to focus on the specific cases is based on two main criteria: (a) all three PSTs participated in the school practicum during the subsequent semester (Spring 2022) and could be observed teaching a STEM lesson in real settings, and (b) data collected during the semester indicate that all three cases had different profiles in terms of their academic performance and their understanding of STEM education. The profiles of the three participants are provided in Table 2 below.

3.3 Data collection

Data collection occurred during the academic year 2021–2022. During the Fall 2021 semester, the PSTs attended the Science Methods Course for Kindergarten from which the data for the first and second research question were collected. During the subsequent semester, the fourth-year PSTs, who formed the three case studies for this research, underwent their final year teaching practicum in different kindergartens. Data for the third research question were collected during the practicum.

To address the first research question, data regarding PST' perspectives on science, STEM and their readiness to teach science, mathematics and technology were collected through tests administered at the beginning, middle and end of the semester. Additionally, their understanding of STEM was assessed through written online reflections conducted at the end of week three (before they engaged with STEM activities) and at the end of week seven (after experiencing STEM activities). Regarding the second research question, lesson plans from three PSTs were collected and subjected to analysis. Furthermore, the PSTs participated in interviews focused on their lesson plans and the rationale behind their design choices. To address the final research question, the three PSTs were observed while teaching a 40-min STEM lesson during their placement. All three PSTs were interviewed to obtain their insights and reflections on the lesson after is completion. Table 3 presents an overview of the data collected for each research question.

3.4 Data analysis

Pre and post-test questionnaires were collected by all participants for the first research question. The first part of the questionnaire

TABLE 3 Overview of data.

Research question	Data collected	Data collection point
R.Q.1. What are kindergarten PSTs views and knowledge of STEM education before and after engaging with integrated STEM?	Views and knowledge of science and STEM Views about readiness to teach science, math, technology, and STEM	pre and post questionnaire (weeks 1, 7, and 12)
R.Q.2. What difficulties do kindergarten PSTs have when designing a STEM lesson plan?	Reflection Group STEM lesson plan Interview with PSTs justifying their choices for the lesson plan	Week 3 and Week 7 Week 11 Week 11
R.Q.3. What difficulties do kindergarten PSTs have when implementing a STEM lesson plan?	Observation of STEM lesson taught during school practicum (for three PSTs) Individual reflection interview with the three PSTs at the end of the observation	Spring semester 2022

TABLE 4 PSTs views on what STEM is before, during and after engaging in an integrated STEM course.

	Week 1 $N = 21$	Week 7 $N = 21$	Week 12 $N = 21$
Category 1: I do not know what STEM education is	18	0	0
Category 2: STEM is a digital platform	1	0	0
Category 3: STEM education has to do with a learning theory	2	0	0
Category 4: STEM education includes science, mathematics, technology, and engineering	0	3	1
Category 5: STEM education has to do with presenting a problem to the students and asking them to solve it using different subjects	0	18	2
Category 6: STEM education has to do with giving a problem to the students, and based on the problem organizing activities that require the skills and knowledge from different disciplines to solve	0	0	18

TABLE 6 PSTs ideas about designing a STEM lesson.

Category of response	Week 3 $N = 21$	Week 7 $N = 21$
Category 1: Do not know how to teach math, science and technology together	5	0
Category 2: Designed a science that will include some mathematics	6	0
Category 3: Designed a sink and float lesson (science) and ask the students to put the objects in categories (mathematics)	4	0
Category 4: Used a robot to teach to the students how to make it move and then use it as part of an assessment activity (i.e., the students give instructions to the robot to move to a place on the ground where the correct response is)	6	4
Category 5: Start with a problem which requires a solution	0	5
Category 6: Start the lesson with a problem and then organize it in a way that would require discussing math and science concepts and the use of technology	0	12

TABLE 5 Self-reported readiness to teach science, mathematics and technology.

Self reported readiness to...	Week 1		Week 12	
	M	SD	*M*	SD
Teach science	3.3	0.8	4.1	0.4
Teach mathematics	3.7	0.8	4.0	0.6
Teach with the use of technology	3.8	0.7	4.1	0.4
Use technology themselves	4.7	0.5	4.4	0.5

included open-ended questions. Individual responses were read looking for patterns related to views and knowledge of STEM education and responses were open coded to create the categories shown in Table 4. The questionnaire also included a part with5-point Likert scale regarding PSTs self-reported readiness. For this part the average score was calculated for all participants and results are presented in Table 5.

Regarding the second research question, the examination of PSTs difficulties when designing a lesson plan was based on: (a) the open coding of the reflective diaries, (b) open coding analysis of their lesson plans and the recordings of their interviews and presentations. The responses to the reflective diaries where read and categories were created (see first column Table 6). Lesson plans were submitted by groups of PSTs (4–5 PSTs per group) and were analyzed looking at: the problem or driving question; the objectives; the teaching approach and pedagogical strategies applied and the content and structure of the activities. During the group interviews the PSTs were asked to justify their choice of topic, the problem/question that they chose, and the teaching strategies included. They were also asked to justify why they consider their lesson to be a STEM lesson plan. Data from the interviews were transcribed and categories were constructed in several analysis cycles that required reading the transcripts several times and coding them again, comparing them with categories that were formed from the analysis of the lesson plans.

Regarding the third research question about PSTs difficulties when implementing a STEM lesson, three PSTs were chosen as case studies. The choice of the three cases was based on the following criteria: (a) the PSTs were registered in the school practicum and could teach at least one STEM lesson as part of their school practicum, and (b) they had different profiles regarding their evaluation in practicum and their views on STEM during the course (see Table 2). PST observations during their teaching were recorded on an observation sheet. The observation sheet was prepared based on the categories developed as part of the analysis of the second research question (integration of subjects, problem-based approach, application of skills by students, PSTs confidence when teaching). The purpose of the reflective interviews with the PSTs after the implementation of their lessons was to understand some of the actions taking placing during teaching. PSTs responses were transcribed and open coded.

4 Results

4.1 R.Q.1. What are kindergarten PSTs views and knowledge of STEM education before and after engaging with integrated STEM?

PSTs views and knowledge on what STEM education is was examined with the use of a questionnaire that was administered during the first week of the semester, in the middle of the semester and at the end of the semester. The results of the first part of the questionnaire, the open-ended questions are presented in Table 4. The first column in the table are the categories developed from the open-coding PSTs responses to the open-ended questions.

As shown in Table 4, the kindergarten PSTs were not familiar with STEM education and were not able to provide a description or a definition. A representative response belonging in the first category was "I have seen the term STEM before but I do not know what it means" (PST 1, Week 1).

In the middle of the semester (Week 7), after the PSTs were presented with some information about STEM education their views changed considerably. At this stage of the course the PSTs considered STEM education as an approach driven by a problem that can be solved using different subjects, but they did not refer to activities or skills and knowledge. A representative example, belonging to category 5 is the following: "Doing STEM education means presenting a problem to the classroom and engaging students with problem solving. The problem should be connected to more than science, for example also include mathematics and technology" (PST 7, Week 7).

At the end of the semester, after participating in an integrated STEM lesson as learners (week 8) and learning about the theory of STEM education, most of the PSTs (18/21) were able to define STEM education as one which involves solving a problem using skills and knowledge from different disciplines. A representative example from category 6 is the following: "When I think about STEM education I immediately think about giving a problem to my class which will act as the driving problem for my teaching. This problem will be the basis to design activities which will use skills and concepts from science, mathematics and technology" (PST 2, Week 12).

Before week 6 the PSTs were also asked to explain in an open-ended question how they could use technology with younger students in the classroom to explore their understanding of technology as a learning tool. Most of the PSTs (15/21) responded that they could use a computer and the interactive whiteboard in the classroom to show pictures or a video related to what they were teaching while fewer PSTs (6/21) talked about using a robot to teach programing skills to the students. This highlights PSTs views of technology as a tool to be used by the teacher to present content.

Table 5 presents PSTs self-reported readiness to teach science, mathematics and technology at the beginning and the end of the semester. The questions were presented in a 5-point Likert scale and PSTs were asked to explain the response in an open-ended question.

PSTs self-reported readiness to teach science, mathematics and use technology in their teaching increased after their participation in the course. However, their self-reported readiness to use technology themselves decreased after the end of the course.

4.2 R.Q.2. What difficulties do kindergarten PSTs have when designing a STEM lesson plan?

Before being taught about STEM education (week 1 questionnaire) PSTs were asked to consider a hypothetical scenario in which they had to teach in the same lesson concepts and skills related to math and science and include technology. They were asked to explore the local curricula for kindergarten and based on what is taught to propose a description of a lesson. The term STEM was not used in the question as PSTs initial questionnaire showed that they were not familiar with this term. PSTs responses to the reflective diary were coded using open coding and the categories developed through the process of reading all responses from the reflective diaries from weeks 3 and 7 and creating the six categories that appear on the first column on Table 6.

As shown in Table 6, PSTs do not understand the meaning of integrated STEM and cannot design an integrated STEM lesson on week 3. Five PSTs directly quote that they do not know how to design a lesson with mathematics, science, and technology, while the remaining PSTs (16/21) suggest lessons in one of the disciplines. Category 3 is specific on sink and float as all four PSTs in the specific category used the sink and float concept in their responses. This is probably linked to experiences these PSTs have from observations they have done in kindergartens earlier in their studies. A representative example from category 3 is: "I decided to teach sink and float as a STEM lesson. After asking students to experiment with different materials to see which float and which sink I will ask them to put them in two groups. I consider this last part as doing mathematics since we also do this in our maths course. So this will be my STEM lesson" (PST 5, week 3).

At the end of week 7, when the PSTs were introduced to STEM education and were presented with some examples of STEM lessons,

TABLE 7 Analysis of lesson plans developed by groups.

	Topic and question/ problem	Objectives	Teaching approach and activities
Group 1	Magnets: How to make a car move without pushing it?	- Asking questions about how to make the car move - Explaining/ reasoning about the process of constructing a car - Construct a car using knowledge from magnetism - Applying measure knowledge to construct car	- Inquiry based learning - Used prior knowledge from science and math - Applied design based thinking for the construction of the car - There is integration between the different topics and the activities are linked between them - No emphasis on technology
Group 2	Volcano: What are volcanoes?	- To learn about volcanoes and how they work - To understand how to move a robot in the different directions - To be able to sort objects based on their size	- Each activity is focusing on one of the objectives and there is no continuation or connection between them - Inquiry based approach is used in each individual activity but there is no integration of the disciplines, they are taught separately
Group 3	Shadows: What are shadows and how to create them?	- To learn how shadows are created - To understand how to change the direction and length of a shadow - To apply math knowledge to measure shadows using their own units of measurement - To use a robot to sort - To be able to sort objects based on their size	- There is a continuation between the activities and integration between math and science activities - Inquiry based approach is used in each activity - Technology is used separately in the final as a way to assess students' understanding of the topic
Group 4	Light/transparency: Which objects are better to hide a present?	- To sort objects based on their transparency - To predict which is the best object to use to hide a present - To apply math knowledge to measure the object and create the best wrapping - To use a robot to sort objects based on transparency	- There is a continuation between the activities and integration between math and science activities - Inquiry based approach is used in each activity - Technology is used separately in the final as a way to assess students' understanding of the topic
Group 5	Bees: Why are the bees important?	- To understand the role of the bees for our environment - To use a model of a bee and pollination (using Lego We Do) to explain pollination	- Inquiry based approach is used in the activities and there is a continuation between the activities - Technology is used as a ready model for students to use to explore how pollination is happening in the environment - There is no reference to math concepts

they were able include in their lessons one of the main characteristics of STEM lessons, starting with a problem (5/12). More than half of the PSTs were also able to identify that the problem should be posted in a way to enable the use of math and science concepts and skills, and the use of technology. A representative example from category 6 follows: "I decided to start with a problem, a scenario. We need to create a cover for our car that is waterproof and can also fit the car. The students must experiment to understand which materials are waterproof and which not, but also need to find ways to measure the car to make a uniform that is appropriate. Therefore, I am using mathematics and science together. I will also introduce technological tools that will help them design the cover, but I need to explore this more to see how to implement it" (PST 2, week 7).

To further explore PSTs difficulties when designing STEM lesson plans, PSTs group lesson plans were analyzed. The analysis of the lesson plans is presented in Table 7.

Based on the analysis presented in Table 7, Group 1 designed a lesson which integrated science, math and engineering through the use of design thinking (students were asked to think of how to design a car, reflect on the process, evaluate their ideas and build the car with the help of the teacher). The lesson included objectives focusing on skills and STEM practices and had objectives for science, math and engineering, but technology was not used in the process. During the interview the PSTs explained that they wanted to design a lesson in which the students would work collaboratively and "engaging in the learning process in a similar way as we did when we experienced the STEM lesson as learners. We came up with this idea based on our knowledge of science but we could not think of any ways to introduce technology in a way that would make sense for the students" (Nicky, Group 1).

Group 2 designed a lesson in which activities on science and mathematics were separate and therefore there was no integration, and used technology as a tool to assess the students. When PSTs in Group 2 were asked to justify their choice of topic and question they said that "the topic of volcano is interesting for the students, this is why we chose it" and when they were asked to explain why this is a STEM lesson they responded that "this is a STEM lesson because we have objectives for science, mathematics and technology and we start with a question for the students. We could not think of other ways to use technology, maybe because we are not familiar with a many technological tools that can be used with younger students" (Ellie, Group 2).

Groups 3 and 4 lessons focused on the integration of mathematics and science only, and technology was used separately as a final activity to evaluate students with the use of a robot. During the interview PSTs from Group 3 justified their choice of topic and question saying that "this topic is part of the curriculum already so we thought that we could modify it in a way to include math and technology as well. It is a STEM lesson as we have included concepts from science, math and we are also using technology at the end as part of the final assessment activity we designed" (Maria, Group 3). Similar was the response from Group 4 members who stated that "We have asked the students to use technology at the end of the lesson as an assessment activity ad we could not find other ways to introduce it in the lesson, but we have focused on math and science knowledge and skills in our lesson using examples from the curriculum" (Silia, Group 4).

Group 5 had a different approach than the previous groups. They chose to use an already constructed robotic Lego model (Lego We Do) of the bee and pollination that was used by the students to help them understand pollination and discuss about the role of the bees in the environment. During the interview the PSTs from group 5 justified their choice to use the robotic model was since by "playing with the bee model the students can see how the bee is taking pollen from the flower and this can help them understand the process of pollination" (Mayia, Group 5). When prompted to explain why this is a STEM lesson Group 5 supported it by saying that it includes technology and science without any further explanations.

4.3 R.Q.3. What difficulties do kindergarten PSTs have when implementing a STEM lesson plan?

For the third research question three kindergarten PSTs were observed implementing a STEM lesson during their school practicum. All groups received feedback on the lessons they designed and could implement during school practicum if they wanted (Table 8).

All three cases taught a 40-min lesson during their placement which was observed by the instructor of the course. Sonia's lesson followed an inquiry-based approach, and the students were actively involved in the activities. After the implementation of the lesson Sonia said that "I felt confident when I was teaching the lesson because we discussed the activities with the other group members, and I was familiar with the concepts involved. We constructed the cars [combination of building blocks and magnets] ourselves in our groups when preparing the lesson, so I was familiar with the difficulties the students had in the process of constructing the cars. What I enjoyed the most was students' excitement" (Sonia). When asked why she did not use technology Sonia said "I am aware that I did not include all the subjects from STEM but I could not think of any productive ways to include technology in this lesson without losing the connection between the activities."

On the contrary, Ariana was not that confident during her teaching, and she reported that during the interview as well. She said that she was anxious that the activities would not work properly and the kids She chose to teach a different lesson than the one designed by her group because as she said, in their lesson they did not manage to integrate the different STEM subjects but they had separate activities for each one of the subjects. Despite the feedback from the instructor, Ariana reported that it was still difficult for her to think how she could change the lesson to improve it. Therefore, she chose a lesson that she had taught before (Sink/Float) and added an evaluation assignment at the end of the lesson using technology. During the interview Ariana was asked why she considers this lesson to be a STEM lesson. Ariana responded that she knows that her lesson "does not fit the STEM criteria as I am only focusing on science, but I added technology at the end to have something from the other disciplines. I did not feel comfortable trying something new with the students and as I did not try it before and did not have the support from my mentor who is not familiar with STEM." Ariana was also asked about the use of technology in her teaching (she used a robotic bee which the students directed to a correct response from those presented on the floor) and explained that she has seen her mentor use this activity in the class often and "students are excited about using the bee. So I thought that since they know how to use it already it will be easier for them and for me."

Lucy was not confident during her teaching as she reported herself during the interview: "I am not very comfortable with the language as this is not my native language and I was stressing when I was teaching." Lucy followed the lesson plan they designed as a group which integrated math and science to teach shadows. She followed an inquiry-based approach and her students were engaged in the process. The final activity, which was using a robotic bee to evaluate students' understanding (similar to what Ariana did) was not connected to the

TABLE 8 Description of cases.

Pseudonym	Description of cases based on findings from R.Q1 and R.Q2
Sonia (PST 2)	She was not familiar with STEM education but developed a good understanding by the end of the course, had high self-reported readiness to teach math, science and technology and high self-reported readiness to use technology herself. Sonia was part of Group 1 in lesson design. When observed during the practicum she implemented the lesson as designed by her group
Ariana (PST 7)	She was not familiar with STEM education but developed a good understanding by the end of the course, had average self-reported readiness to teach math, science and technology and low self-reported readiness to use technology herself, none of which improved. Sonia was part of Group 2 in lesson design. When observed during the practicum she implemented a lesson from the curriculum which she thought was STEM
Lucy (PST 9)	She was not familiar with STEM education but developed an average by the end of the course (start with a problem), had average self-reported readiness to teach math, science and technology and average self-reported readiness to use technology herself, none of which improved. Lucy was part of Group 3 in lesson design. When observed during the practicum she implemented the lesson as designed and presented by her group

activities she did before. When asked about her lesson during the interview she said that it was STEM because of math, science and technology and she considered that all three subjects were integrated. Lucy said "I taught the lesson in the way we designed. When I saw my mentor use the robot bee I was convinced that this was a good use of technology." When she was asked about the objective supporting the use of the robot bee, she connected this to the evaluation of the lesson and not to learning digital skills.

5 Discussion

5.1 R.Q.1. What are kindergarten PSTs views and knowledge of STEM education before and after engaging with integrated STEM?

Findings for the first research question reveal that kindergarten PSTs were not familiar with STEM education and did not have any previous experience with STEM education either as school students or during their studies at the university. The PSTs were familiar with the different subjects of STEM, and were taught these subjects as part of their school curricula, but the term STEM was not familiar to them. This can be expected since in their educational system STEM education (emphasis on integrated STEM) was just recently introduced for students in primary and early secondary schools. Furthermore, the program of study at the university does not have a dedicated course on STEM Education. This finding is similar to previous studies which highlight PSTs and teachers' lack of knowledge and understanding of STEM education (DeJarnette, 2018) and highlight the need for teacher preparation programs to focus on the preparation of PSTs to familiarize them with STEM education and the different educational principles (Yıldırım, 2021). This need has been highlighted in various policy reports, with a special emphasis on preparing pre-and in-service teachers to support students across all educational levels (National Academy of Engineering and National Research Council [NAE/NRC], 2014).

Another important finding is that teachers views on STEM education progressed after the theoretical introduction to STEM, but considerable improvement and understanding of STEM education was evident after they engaged as learners in a STEM lesson specially designed for kindergarten students (week 8). At the end of the course the PSTs were able to explain what a STEM approach is and provide multiple examples on how to apply it to their lessons. This finding is similar to findings from previous studies (i.e., Chen et al., 2021; Yıldırım, 2021) which highlight the need for PSTs to engage as learners to be able to reflect on the structure of a lesson and the difficulties that their students might have. Previous studies (i.e., Yıldırım, 2021) have also highlighted the need for professional development on STEM education for kindergarten PSTs, but also the need to support them during the design stage of developing their lessons.

A third finding is related to PSTs' self-reported readiness to teach the different subjects separately (science, math and incorporate technology) that was improved at the end of course. Their self-reported readiness to use technology themselves declined. One hypothesis is that PSTs were not familiar with many types of technologies that can be used in the classroom as tools to support in the learning process (i.e., augmented reality tools, VR tools, programming robots, programming apps) and could not understand the complexities of using these technologies before the course. Through the activities of the course which involved among other using different types of technologies as part of the lesson they could realize the levels of complexity. This finding highlights the need to acquainting PSTs with different technological tools and support them to use them themselves as learners first, and then develop the competence to use them as part of the teaching process.

5.2 R.Q.2. What difficulties do kindergarten PSTs have when designing a STEM lesson plan?

Findings for the second research question show that PSTs were not familiar with designing integrated STEM education lesson plans, and this can be expected given that they were not familiar with STEM education at the begging of the semester. This finding has been recorded in previous studies which explored kindergarten PSTs ability to design lesson plans (i.e., Yıldırım, 2018). PSTs showed an improved ability to design lessons after engaging with main concepts and pedagogical strategies linked with STEM during week 7, but still their understanding of a STEM lesson is mainly linked to the fact that this should be starting with a problem, and some understand the need to link this problem to knowledge and skills from math, science and technology. Findings from the group lesson plans that were designed and presented during week 11 show that when working in groups PSTs designed lessons which offered integration between two subjects, mainly math and science. One hypothesis is that PSTs are more familiar with these two subjects and therefore can more easily find connections between the two. Another hypothesis is that for both subjects they had access to the local curricula which offers examples of lesson plans, and by using these examples they could more easily adapt them to consider integration. This finding, of STEM lessons focusing mostly on the subjects on math and science only is reported elsewhere in the literature as well (Ryu et al., 2019). An additional finding from the lesson plans is that technology is used in the lessons as a presentation tool, and not as an actual tool that can be used for the students to help them improve their digital competences. One hypothesis for this finding, which is supported by the findings from the first research question, is that PSTs do not have knowledge of technological tools and how they can used in the teaching.

5.3 R.Q.3. What difficulties do kindergarten PSTs have when implementing a STEM lesson plan?

The case studies show that two of the PSTs designed integrated STEM lessons, with one of them focusing on the integration of two topics, science, and math, and the other focusing on the inclusion of engineering as well through, and one of them was not able to integrate any of the subjects. Findings for the third research questions show that only one of the PSTs was able to implement the lesson as designed, placing an emphasis on problem-based learning and inquiry approach integrating three of the disciplines. One of the PSTs chose to teach a science only lesson that was different from the one they designed in their group. She made this decision because she did not feel confident and did not have support from her mentor, who was not familiar with STEM. The third PST taught a science and math lesson which used technology as a presentation or assessment tool. The findings from the third research question show that PSTs have difficulties in implementing a STEM lesson in their class. Their self-reported readiness to teach the subjects separately might be a predictor on their uptake of the lessons and how they implement them. This can be supported by the finding that considering that Sonia (case study 1) who had higher self-reported readiness was better in designing and implementing the lesson. This has been highlighted in the literature before and is connected with PSTs' self-efficacy (Campbell et al., 2018) which seems to predict their ability to teach. Another important finding from the third research question is PSTs lack of understanding on how to use technology with their students in the class. None of the PSTs has used technology in a way that promotes students' digital skills and as already mentioned in the findings for the first research question this might be related to their lack of knowledge of technological tools.

6 Conclusion

STEM education is becoming more popular, as the integrated STEM approach can help students acquire 21st century skills and competences. The need to start introducing integrated STEM approaches from an early age is linked to the need to provide skills and dispositions from an early age (OECD, 2019). The findings of the current study shed light on early years education, and on the fact that kindergarten PSTs lack the skills, knowledge and self-efficacy that can support them in developing and teaching STEM lessons. This finding is not irrelevant from teacher educators' lack of cohesive understanding of STEM education (Kelley and Knowles, 2016), or the fact that a coherent STEM education framework is not agreed upon between researchers, educators and policy makers (Evagorou et al., 2020). What this study supports is the need for a coherent STEM education framework, and preparation of STEM educators to introduce STEM. Furthermore, what is highlighted is the need for teacher preparation programs in line with new views in training (Putnam and Borko, 2000). These programs should focus on preparing kindergarten teachers to understand what STEM is, but also support them in the process of designing and implementing STEM lessons. Furthermore, in order for the PSTs to be able to design STEM lessons, knowledge of the different disciplines involved in STEM should be acquired, both from the perspective of a learner (Campbell et al., 2018), and the perspective of an educator (Evagorou et al., 2020). The modified model of development proposed as a reflection from the findings of the study is for PSTs to be engaged in STEM as learners first, with an emphasis on all different STEM subjects, and then reflect of the process and the pedagogical practices that were used in the process. In this way PSTs will acquire the knowledge and pedagogical practices that will help them improve their readiness and self-efficacy to teach STEM. Furthermore, during their development PSTs need to engage in examples of STEM teaching in schools, something that is lacking based of the findings of this study. Therefore, mentors should also participate in professional development using a similar structure a PSTs, and supported in implementing STEM activities in their classes as role models of kindergarten PSTs. Implications from this study include the design of a teacher training courses to support PSTs during their studies and also in their early career, but also include mentors as part of the training course to support them acting as positive role models.

Limitations of the study include the emphasis on the science, mathematics and technology practices only, excluding engineering practices. This is mainly due to the structure of the local curricula which does not include engineering practices, on the emphasis of the course on science methods and the expertise of the departmental team which does not include an engineering expert.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because there was no ethical approval requirement at the institution for participants over 18. Only informed consent by the participants was required. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

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