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Research Article

Investigating teachers' expectations from a professional development program for integrated STEM education

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Teacher qualifications are a crucial element for successfully implementing integrated STEM education. Research suggests that a STEM education program should be compulsory for all STEM-related teachers. In this study, as STEM education researchers, we asked teachers from different disciplines about their expectations from a professional development (PD) program for integrated STEM education. Six hundred sixty-four teachers participated in the study. We examined the PD expectations of middle school science, mathematics, and computer science teachers regarding pedagogical knowledge, technological knowledge, benefits, and PD program design. In addition, we discussed how these expectations changed based on teachers' subjects. Qualitative data were analyzed through content analysis. In terms of pedagogical knowledge, teachers want to use innovative approaches while integrating ICT into the learning and teaching process. Teachers' expectations of developing ICT competencies in terms of technological knowledge are at the forefront. In the design of such programs, the most critical expectations of teachers are to provide collaborative working environments, thus increasing their opportunities to work with colleagues from different disciplines and their capacity to do interdisciplinary work. Teachers' willingness to participate in a PD program related to integrated STEM education has four underlying expectations: student benefit, professional benefit, personal benefit, and context benefit. Teachers' expectations vary according to the subject area.

Keywords: Integrated STEM; Teacher development; Professional development; Expectations and needs

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1. Introduction

The most crucial educational challenge of our time is to educate students in a way that can respond to interrelated economic, social, and scientific issues, despite the traditional single-discipline-based, structure of education with distinct disciplinary borders (Howlett et al., 2016). The importance of STEM (science, technology, engineering and math) education becoming widespread and emphasizes approaches within this context (English, 2016; Falloon et al., 2020; Honey et al., 2014; Li et al. 2020; Ryu et al., 2019; Zhou et al., 2020). According to Honey et al. (2014), the goals of STEM education for students include STEM literacy, 21st-century competencies, STEM workforce readiness, the ability to connect STEM disciplines, and interest and

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participation. There is a trend towards the integration of STEM disciplines by connecting the STEM disciplines (Cheng et al., 2020; English, 2016; Johnson, 2013; Martín-Páez et al., 2019; Stohlmann et al., 2012; Thibaut et al., 2018; Zhou et al., 2020). This trend towards integrating science, technology, engineering, and mathematics in K12 STEM education (Dare et al., 2018; Ring et al., 2017) is called integrated STEM education.

Science and mathematics have historically always been taught as distinctly separate school disciplines at the primary and secondary school level, and education continues based on a single discipline model in schools (Martín-Páez et al., 2019; Ortiz-Revilla et al., 2020). Despite this disciplinary structure, national and international policies for STEM education continue to encourage teachers to explore interdisciplinary connections (English, 2016; Falloon et al., 2020). Teachers are held responsible for teaching a single discipline, but expected to integrate more than one discipline to implement integrated STEM education (Johnson, 2013; Thibaut et al., 2018; Zhou et al., 2020). Although interdisciplinary teaching practices are emphasized in integrated STEM education, it is up to teachers to determine their instructional design (An, 2016).

Teacher qualifications are a crucial element for successfully implementing integrated STEM education (Song, 2020). Given the current state of teacher education programs (Wilson, 2011), it is highly contradictory to ask teachers to implement STEM curricula that integrate different disciplines. Nevertheless, teachers' shortage of opportunities to engage in integrated STEM-related PD continues, and the contemporary curriculum does not support teachers' integration efforts (English, 2016). This highlights the importance of teachers' professional development (PD) in integrated STEM education.

It is essential to understand what teachers understand as integrated STEM education (Ring et al., 2017), to identify the necessary teacher competencies (Song, 2020), and to use these understandings to support their PD (Stohlmann et al., 2012). This study investigates the expectations of science, mathematics, and computer science (CS) teachers from a PD program for integrated STEM education. These expectations are important to meet the PD needs of teachers in the context of integrated STEM education Thus, answers to the following research questions guided this study:

RQ 1) What are the expectations of teachers from the PD program?
  a. What are the expectations in terms of pedagogical knowledge?
  b. What are the expectations in terms of technological knowledge?
RQ 2) In what ways do teachers expect to benefit from the PD program?
RQ 3) What are the expectations of teachers in terms of the design of the PD program?
RQ 4) How do the expectations of teachers differ according to their subject?

1.1. Integrated STEM Education

There are many different understandings of integrated STEM education (English, 2016). Sanders (2009) defines integrated STEM education as including approaches that explore teaching and learning between two or more STEM subject areas and/or between a STEM subject and one or more school subjects. Johnson's (2013) identified integrated STEM as "an instructional approach, which integrates the teaching of science and other STEM disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and interdisciplinary themes and skills" (p. 367). Vasquez et al. (2013), on the other hand, defines different levels of integration, from teaching concepts and skills separately in each discipline, to teaching knowledge and skills from two or more disciplines applied to real-world problems and projectsThe only issue on which consensus is achieved is that some issues should be considered "both a curriculum and pedagogy" on what and how to teach in integrated STEM education (Margot & Kettler, 2019, p. 2).

Integrated STEM education has a lot of potential for student learning. Integrated STEM education has the potential to develop students' 21st-century skills (Hourigan et al., 2021). Integrating STEM disciplines provides students with real-world learning experiences in an interdisciplinary context (Dare et al., 2018). Becker and Park (2011) found that students achieved higher success when integrative approaches on STEM subjects were used. The integration of knowledge should be both within and between disciplines, and students should explicitly see on the interconnectedness of science, technology, engineering, and mathematics (Honey et al., 2014). The success of these calls to improve the quality and integration of STEM in K–12 classrooms depends on teachers and thus the PD efforts that will transform teachers' knowledge, beliefs, and attitudes (Ring et al., 2017). More research and discussion is needed about the knowledge, experience, and background that teachers need to successfully implement integrated STEM and have the desired impacts on student learning (Stohlman et al., 2012).

1.2. Integrated STEM Teacher Education

Research suggests that a STEM education program should be compulsory for all STEM-related teachers (Herro & Quigley, 2017; Song, 2020). This is particularly true for practicing teachers because many teachers have never had this type of learning experience in their teacher education (Morrison et al., 2021). Nevertheless, adequate PD opportunities do not exist to help teachers experience integrating STEM into their teaching (Asghar et al., 2012; Stohlmann et al., 2012). PD programs for integrated STEM education, significantly impact teachers' knowledge and concepts of integrated STEM teaching (Ring et al., 2017), even short-term PD (Shahali et al., 2015). However, more research is needed on the knowledge, experience, and support that teachers need from integrated STEM PD (Stohlman et al., 2012). In this context, studies are addressing the PD of teachers for integrated STEM education (Baker & Galanti, 2017; Estapa & Tank, 2017; Hudley & Mallinson, 2017; Hourigan et al., 2021; Kelley et al., 2020); nevertheless, there is a necessity for studies that focus on teachers' needs and expectations, thus considering the factors that would affect teachers' PD success (Affouneh et al., 2020).

Teachers in various STEM disciplines have different perceptions of STEM integration, leading to different classroom practices (Wang et al., 2011). On the other hand, teachers' conceptions of STEM integration is sensitive and influenced by their PD experiences (Ring et al., 2017). Therefore, it is likely that teachers accure different benefits from PD programs. The widely applied one-size-fits-all STEM PD approach is inappropriate for teachers from different backgrounds and experiences (Baker & Galanti, 2017). The lack of diagnostic information about what teachers should learn through STEM PDs, not considering the diverse needs of teachers, and ignoring their previous knowledge and experiences are important problems of one-size-fits-all PDs (Wilson, 2011). Instead, models in which teachers' opinions and suggestions are included in PD designs should be employed. Estapa and Tank (2017) focused on customized PD design and results by exploring to what extent classroom teachers, student teachers, and engineers, each with different background knowledge, skills, and needs, could use the engineering design context to integrate and incorporate STEM concepts into the primary school classroom. Such PDs also encourage STEM teaching leadership (Baker & Galanti, 2017).

Hudley and Mallinson (2017) examined the needs of STEM educators to develop a PD program that focused on cultural and linguistic differences in STEM education. University based PD projects (e.g., Kelley et al., 2020; Ring et al., 2017) tend to be based on teachers' needs guided by education standards, especially long-term PD program designs for integrated STEM education.

In summary, teacher is necessary to promote integrated STEM education (Shernoff et al., 2017). It is essential to formulate PD to promote teachers ability to integrate disciplines, understand pedagogical approaches, and link 21st-century competencies with the real world (Kurup et al., 2019). PD developers and teachers should cooperate in designing such a PD program (Brown & Bogiages, 2019). Thus, in this study, as STEM education researchers, we asked teachers from different disciplines about their expectations from a PD program for integrated STEM education. We wanted to strengthen the link between theory and practice in the context of teachers' needs. Specifically, we examined the PD expectations of teachers in terms of pedagogical knowledge, technological knowledge, benefits, and PD program design. In addition, unlike other studies, we examined how these expectations changed based on the different subject teaching assignments.

2. Methodology

2.1. Study Group

Six hundred sixty-four middle school teachers voluntarily participated in the study . The majority of is the participants were female (60.5%) (See Table 1). Most of the participants were relatively new teachers, with a seniority of 1-10 years (60.1%). The education level of most teachers was at the undergraduate level (68.5%), with 74.5% working in public schools and 84.3% at the secondary school level. 65 out of 221 mathematics teachers, 122 out of 329 science teachers, and 24 out of 114 CS teachers stated that they have not participated in any PD related to STEM education to date.

Table 1
Demographic information of the study group

		Computer Science		*Science*		*Mathematics*		*Total*	
		f	%	f	%	f	%	f	%
Sex	Female	50	43.9	222	67.5	130	60.5	402	60.5
	Male	64	56.1	107	32.5	91	39.5	262	39.5
Level of education	Undergraduate	78	68.4	238	72.3	139	68.5	455	68.5
	Graduate	33	28.9	89	27.1	68	28.6	190	28.6
	PhD	3	2.6	2	0.6	14	2.9	19	2.9
School type	State school	81	71.1	260	79	154	74.5	495	74.5
	Private school	21	18.4	55	16.7	32	16.3	108	16.3
	Science and art center	12	10.5	14	4.3	35	9.2	61	9.2
School level	Secondary	91	79.8	302	91.8	167	84.3	560	84.3
	High school	23	20.2	37	8.2	54	15.7	104	15.7
Seniority	1-5 years	32	28.1	109	33.1	48	28.5	189	28.5
	6-10 years	15	13.2	110	33.4	85	31.6	210	31.6
	11-15 years	51	44.7	66	20.1	49	25	166	25
	16-20 years	15	13.2	28	8.5	33	11.4	76	11.4
	21 years and more	1	0.9	16	4.9	6	3.5	23	3.5
Total		114	17	329	50	221	33	664	100

2.2. Data Collection and Analysis

This study was conducted in the context of an integrated STEM PD program in Turkey. Teachers who voluntarily applied to participate in this program were asked about their expectations for the PD program. The data were collected through an electronic form. In addition to the demographic information of the teachers regarding the subject, gender, education level, school type, school level, and seniority, they were asked to answer an open-ended question: "What is your expectation from a PD program for integrated STEM education?".

Content analysis of the qualitative data was performed using the NVivo 12 program. The analysis of the data was carried out iteratively through an inductive method. The researchers followed the content analysis steps by Weber (1990). First, the first author read all the data and created a preliminary coding list for coding . In the next step, coding and quotations were discussed with the second author using he preliminary coding list. As a result of the discussion, the category list was revised. Then the coding was done again by the first author. The second round of coding was reviewed with the second author. Reading and coding of the data continued until a coding list covering all the data was created. After the coding list was finalized, the themes were determined, the definition of the themes was created, and the thematic framework was put forward. After that, the third author was asked to code 25% of the data set, and Cohen's Kappa value was calculated for intercoder agreement (κ=.89). Accordingly, it was observed that the agreement between coders was high.

3. Findings

A total of 652 codes were recorded and the themes obtained as a result of this analysis are given in Table 2.

3.1. Teachers' Expectations from a PD Program for Integrated STEM Education

Teachers put forward their expectations from a PD program for integrated STEM education as pedagogical knowledge and technological knowledge, with pedagogical knowledge being more prevalent.

3.1.1. Pedagogical knowledge

This theme sheds light on teachers' perspectives and expectations from PD programs for integrated STEM education. The pedagogical knowledge theme included contemporary topics in STEM education of the last ten years, such as ICT integration, innovative approaches, and designing the learning and teaching process.

ICT integration competencies constituted an essential part of teachers' expectations from a PD program. This expectation mainly included improving the knowledge and skills of teachers to integrate ICT into their lessons, connecting subject areas with ICT, and improving their skills in using ICT in STEM activities. Some of the teachers' statements are given below, with quotes designated by subject area.

> To learn new approaches in integrating ICT into the lesson, gain different interdisciplinary perspectives, raise my basic skills to higher levels, and learn applications that will make the activities and teaching more effective. (M-088)

> To see innovative technological applications and better understand their integration into lessons. To be able to work between disciplines, to give more space to ICT in STEM activities. (S-269)

> Gaining competencies that can best integrate technology, mathematics, and science in learning-teaching processes and adapt them to my lessons in the best way. (S-048)

Learning and applying innovative approaches was another expectation of teachers from the PD program. Teachers expected to develop their knowledge and skills to use innovative approaches and methods such as design thinking, engineering design processes, game-based applications, computational science applications, and e-learning in learning and teaching processes. In addition, teachers expected to develop their skills in handling interdisciplinary content with innovative approaches and how innovative approaches can be implemented in the classroom. Examples of teachers' statements are shared below.

> I aim to plan more productive lessons for my students with new approaches and methods developed in the 21st century. (S-184)

> This program will be a crucial training in fields such as game-based applications, computational science applications, and e-learning applications to eliminate my theoretical deficiencies and increase my pedagogical knowledge. (S-197)

> To carry the integrated course teaching methods and innovative techniques to the classroom environment in practice. (CS-104)

> To be aware of innovative methods in educational technologies and to gain knowledge to apply in my lessons. (M-274)

Another expectation of teachers in terms of pedagogical knowledge was to learn how to design teaching processes. Teachers expected to develop their knowledge and skills to design effective interdisciplinary lessons, materials, and STEM activities that they could use in their lessons.

Table 2
Themes obtained as a result of the analysis and the thematic framework developed

Theme	*Sub-theme*	*Description*	*Coding frequency*
Pedagogical knowledge	Information and communication technologies (ICT) integration competencies	Developing their knowledge and skills to integrate ICT into learning and teaching processes	85
	Innovative approaches	Developing knowledge and skills on innovative approaches and methods (such as design thinking, engineering design processes)	71
	Designing teaching process	Designing teaching processes that will enrich the course and increase its efficiency	59
	Designing learning process	Designing learning processes focused on product development in which the student is active	21
Total			236
Technological knowledge	ICT	Developing knowledge and skills related to ICT	74
	Coding and robotic	Developing knowledge and skills in the fields of coding, robotics, programming	70
Total			114
Perception of benefit	Student benefit	Contributing to the development of students in terms of skills and qualifications that 21st-century learners should have, contributing to students' self-realization and learning processes	66
	Professional benefit	Developing and enriching existing knowledge and skills professionally	66
	Personal benefit	Developing and enriching their existing knowledge and skills in terms of personal development	53
	Context benefit	Sharing and disseminating the knowledge, skills and experiences gained as a result of training with other teachers in their schools and in the region where they work	30
Total			215
Program strategy	Conduct interdisciplinary studies	To carry out interdisciplinary studies that allow the integration of different fields and set an example for the future work of teachers.	24
	Work with other disciplines	Gaining awareness of cooperation with other fields, working to combine one's field with other fields, and working collaboratively with other fields	23
	Collaborative work environment	Working collaboratively with other colleagues and learning from their knowledge, skills, and experience	40
Total			87
Total codes			652

Examples of teachers' views on this are given below.

> To create and implement an interdisciplinary lesson plan using various educational technologies, learn lesson designs for global problems in which technology is integrated, and participate in workshops. (S-124)
>
> I want to reflect on the lesson plans that will emerge from integrating science, mathematics, and CS subjects, which are essential in the interdisciplinary approach, to my lessons. (CS-090)
>
> To make interdisciplinary course designs more effective. (S-296)
>
> To learn designing interdisciplinary teaching processes and materials. (S-063)

The last expectation of teachers from the program in terms of pedagogical knowledge was design of the learning process. Teachers expected to develop their knowledge and skills in designing learning processes in which students are active throughout the lesson, produce solutions on real world problems, and produce a product at the end of the process. Examples of teachers' opinions are as follows.

> To enable students to play an active role in the lessons and produce a product with the knowledge they have learned at the end of the lesson, and to allow the lessons to turn into active communities where active and productive children take part, rather than a passive classroom where the teacher sits in fixed rows and listens to the teacher. (CS-049)
>
> To help my students to create learning environments where we can think about real-world problems and produce solutions more creatively in my mathematics lessons. (M-121)

When teachers' expectations for pedagogical knowledge were examined, it was seen that these expectations are closely related to each other. For example, a teacher stated that they wanted to benefit from innovative approaches while designing the learning process as "By increasing the use of technological and innovative applications in the Science course, I would like to create learning environments that appeal to more visual intelligence, more fun, inquiry-based, goal setting and gradual feedback towards reaching the goal." (S-010)

Teachers want to learn how to use innovative approaches to integrate ICT into the learning and teaching process and to be able to design interdisciplinary learning and teaching processes. If we demand an increase in classroom practices for integrating disciplines due to the nature of integrated STEM education, we need to support the development of teachers' pedagogical knowledge. This study shows these expectations of teachers.

3.1.2. Technological knowledge

When the teachers' expectations from the program regarding technological knowledge were examined, two issues emerged: (i) ICT and (ii) coding and robotics. Teachers' expectations of increasing their knowledge and skills to use ICT more effectively in their lessons and to keep up with developing technologies come to the fore. As one teacher, S-005, stated that they wanted to learn to use Web 2.0 applications in their lessons in order to be able to implement STEM: "Being able to actively implement STEM applications, adapting the use of Web 2.0 tools such as Kahoot, Quiver to science lessons, learning innovations in ICT." Examples of other teachers' opinions are provided below.

> To have comprehensive knowledge and practical skills on making ICT more active with other disciplines in my courses. (M-110)
>
> In order to be able to use ICT interdisciplinary in a more qualified way, I hope that by learning the applications and tools that I do not know, both to transfer them to my students and to contribute to my learning process. (M-188)
>
> It is to help my students to establish the connection between science and technology by coming to a level where I can use ICT more effectively in my lessons. (S-310)
>
> I want to acquire the competence to use ICT technologies more actively in my field. (S-243)

Another expectation of teachers from the program regarding technological knowledge was to increase their knowledge of coding and robotics. Specifically, teacher wanted to be able to transfer this knowledge to their lessons, carry out their studies in this field, and use interdisciplinary practices. For example, one teacher, S-037, claimed that her field demanded coding-style STEM training: I want to attend coding-style STEM training because now our field demands such training, but we are deprived in small places. I want to improve myself through this program. Examples of other teachers' opinions are presented below.

> To be able to improve my knowledge about the tricks of collaborating with my lessons and robotic coding. I expect to be able to improve my knowledge about my courses and the tricks of collaborating with robotic coding. (M-202)

> Gaining knowledge and skills about transferring coding and algorithm-based education to lessons. (S-175)

Teachers' expectations in terms of technological knowledge are parallel with studies on STEM education in recent years (Chaipidech et al., 2021; Kafyulilo & Fisser, 2019; Smith et al., 2015). The use of ICT, coding, and robotics in the context of technology in STEM education is quite common. It is expected that teachers want to keep up with this trend and to improve themselves in this area. For example, one of the science teachers stated:

> As a science teacher, I would like to receive an in-depth education on my general knowledge of ICT. I think that we, as science teachers, do not get enough knowledge on this subject academically. I would very much like to complete my deficiencies in this regard. (S-144)

3.2. Teachers' Expectations of Benefits from a PD Program for Integrated STEM Education

The majority of teachers' perceptions of benefits from the STEM PD program were student benefits and professional benefits, followed by personal benefit and context benefit (see Table 2).

3.2.1. Student benefit

The expectations for student benefits from a PD program for integrated STEM education fell into two sub-themes: (i) to develop the 21st-century skills and qualifications of students and (ii) to enable the student to realize themselves and learn better.

Teachers expressed that they wanted to raise their students as individuals who can produce solutions to real-world problems, think by integrating different disciplines, think scientifically, be aware of their abilities, and realize themselves. Examples of teachers' statements about their expectations of student benefits from a PD program for integrated STEM education are as follows:

> I want to raise individuals who can produce solutions to real problems, realize designs, think by bringing different disciplines together, and have scientific thinking skills. (S-132)

> To be able to guide students who can offer solutions to real-world problems by approaching them interdisciplinary, and to raise students who can think in this way. (M104)

> I am here with an interdisciplinary approach that will enable students to think differently and increase their ability to search for new solutions to various processes by explaining that coping with problems in daily life also includes mathematics. (M-089)

> I want to increase my knowledge in creating the interdisciplinary cooperation necessary for students to have the skills to produce solutions to real-world problems. (CS-103)

Teachers expect to be helpful in the permanence of learning and in transforming their students' theoretical knowledge into practice. A teacher's statement regarding this is as follows:

> I want the information I teach to my students to be more permanent, and I want to be more helpful in transforming the theoretical knowledge they have learned into practice. (M-026)

3.2.2. Professional benefit

Another essential aspect of teachers' expectations for benefit from a PD program for integrated STEM education was professional benefit. Teachers wanted to take their PD to the next level, have the knowledge and skills that will appeal to the 21st-century classrooms, and develop themselves to be able to implement interdisciplinary education. Examples of teachers' statements are as follows:

> One of the essential concepts in education is interdisciplinary communication, but this is the weakest point for teachers. I also feel lacking in this aspect. I find these practical trainings very effective in terms of my PD. (S-159)
>
> To be able to develop interdisciplinary learning, project-based learning professionally and apply it in my lessons. (CS-033)
>
> Teaching with an interdisciplinary approach is very effective for students, so I want to improve myself. With this training, interdisciplinary thinking can be developed by looking at it from different angles. (M-148)
>
> As a science teacher, I support the understanding of interdisciplinary education. This program will increase my professional knowledge. I think I will give better education to my students. (S-226)

3.2.3. Personal benefit

Teachers stated that they wanted to improve themselves because they were interested in technology, ICT, and STEM education. The difference between these expectations and professional benefits is that teachers associated their expectations with their personal interests, perspectives, and motivations, whereas in professional interest, expectations were justified in the context of students, teachers, and schools. Sample expressions of teachers regarding these expectations are given below.

> Opportunity to improve me, apply and disseminate the knowledge I will learn effectively and efficiently integrate into the digitalization process of the 21st-century. (M-174)
>
> I want to participate to improve myself and learn something new. (M-051)
>
> It is hard to say that I will only have one expectation, but in general, I believe that I can improve myself and that it will distance me from everything that pushes me to be stagnant in this education system. (M-211)
>
> Since I also like to deal with technology, I want to improve myself in this sense. (S-038)

3.2.4. Context benefit

The last of the teachers' expectations to benefit from the program was the context benefit. Teachers expected to use the knowledge, skills, and experiences they gained from the PD program to share and disseminate with other teachers in their schools and in the region where they work . Examples of teachers' statements about context benefit expectations are given below.

> I am running a project as an officer in the Provincial National Education R&D. Therefore, I want to pass on what I have learned to teachers. (CS-029)
>
> I am a teacher in a region with limited opportunities. I aim to apply it to my school first and then spread it to my other colleagues. (CS-096)
>
> There are not many such studies in my school and district. I aim to contribute to improving myself and my school and then my district through researches in my way. (CS-035)

Teachers, regardless of subject, stated that they are always trying to keep themselves current with changes in the field. Although there are different reasons behind this, the main expectation of the teachers was to stay up to date. In short, in this theme, teachers wanted to be open to continuous development through all kinds of education to keep up with the times. Examples of teachers' statements are given below.

> To guide individuals with high creative intelligence who can solve today's problems with an interdisciplinary, holistic approach and think algorithmically. I want to improve my professional skills in this regard. (M-031)
>
> I want to contribute to my professional and educational development by directly participating in original and innovative studies that facilitate learning by establishing connections and interactions between different disciplines. (S-169)
>
> I want to renew my teaching knowledge by expanding my perspective with interdisciplinary interaction with science, mathematics, and CS educators to organize project-based activities and studies on 21st-century education. (M-107)

> To prepare our students for the future. In order to do this, we need to anticipate future situations. As a teacher, we must take all the necessary training and improve ourselves constantly. (S-140)

Perceptions of benefits (professional, personal, context, and student benefits) were intertwined. While the emphasis of teachers who want to improve themselves in the professional sense is student, school, teacher, the emphasis of the context benefit is the school, other teachers, and the region. What stands out in the context of benefit is that it includes teachers' expectations from socio-economically inadequate regions. While the benefit to the student stands out as the self-realization of the student and the development of 21st-century skills, teachers think that they cannot provide these to their students without developing themselves professionally in a sense. A teacher's statement is as follows:

> I want to develop myself better, especially in terms of ICT. Therefore, I want to benefit my students more. I think I will share the information I have gained from here with my students; in this way, I will improve myself and think it will be more beneficial for my students. (S-273)

3.3. Teachers' Expectations for the Design of a PD Program for Integrated STEM Education

Interdisciplinary work rose to the fore in terms of teachers' expectations for the design of a PD program for integrated STEM education, this included sub-themes of *conduct interdisciplinary studies* and *work with other disciplines*. Due to the nature of integrated STEM education, interdisciplinary studies should be carried out. For this, teachers from different disciplines are expected to come together in a collaborative working environment. However, the education system based on a single discipline in schools does not make this possible. The teachers' expectations from the program design show that teachers are aware of this need and demand support.

The teachers expected to come together with other colleagues and benefit from their knowledge, skills, and experience, to share their knowledge, skills, and experiences with other teachers, to conduct interdisciplinary studies, and in this context, to work in collaboration with teachers from other disciplines. The teachers wanted to be involved in a program that will mutually contribute to the PD of both themselves and their colleagues in an active and collaborative learning environment. Examples of teachers' views on these expectations are given below.

Conduct interdisciplinary studies:

> My expectation from this program is to learn how to integrate STEM disciplines better. I attended a training under the name of STEM educator training before, but they showed us drones, vex, 3D printers, etc., but the part about how to use them actively in our subjects was insufficient. There was no smooth transition between the subjects; I expect this program to connect the subjects systematically. I expect theoretical knowledge as well as practical knowledge. (M-164)

> I am not at a sufficient level in interdisciplinary education, in preparing a lesson plan in areas outside of my field, or in making connections with other fields while explaining the subject of my field. I think this program will help me in this sense and take me to higher levels. (CS-113)

> To see how different disciplines can be adapted to my science subject, with sample applications, to have experience in this field. (S-172)

Work with other disciplines:

> Students have difficulty in understanding the subject when mathematics is involved in some subjects in the science class. I am having a hard time explaining too. In such cases, I expect to find answers to questions such as how to cooperate between disciplines, find solutions, etc. (M-041)

> We do not benefit from the cooperation between different disciplines while teaching our lessons at our school. I think the reason for this is that teachers have difficulties establishing these interdisciplinary connections, and they do not have much knowledge on this subject. We can apply it in our lessons with my friends at school by working with different disciplines in this program. (S-267)

Collaborative work environment:

> I want to participate to learn and share my knowledge with other participants. (M-180)

I want to meet my colleagues in different subjects from different provinces and learn a lot from their experiences. (S-167)

I would also like to share our experiences with the participants. We became 10th place globally by participating with my team in the 2018 VEX Robotics World Championship held in America. (CS-038)

To improve me professionally and in collaborative work with other subject teachers. (CS-011)

3.4. Change of Teachers' Expectations from a PD Program for Integrated STEM Education according to Subject

In order to investigate whether teachers' expectations from a PD program for integrated STEM education differed by their subject, the codes were examined based on subjects (See Table 3). The findings are presented for science, mathematics, and CS teachers in terms of pedagogical knowledge, technological knowledge, perception of benefit, and design of PD.

Table 3
*Distribution of code according to subjects**

Theme	*Sub-theme*	*CS*		*Math*		*Science*		*Codings*	
		f	%	*f*	%	*f*	%	*f*	%
Pedagogical knowledge									
	ICT integration competencies	3	8.57	37	50.68	45	35.16	85	36.02
	Innovative approaches	17	48.57	14	19.18	40	31.25	71	30.08
	Designing teaching process	9	25.71	14	19.18	36	28.13	59	25
	Designing learning process	6	17.14	8	10.96	7	5.47	21	8.9
Technological knowledge									
	ICT	0	0	27	54	47	79.66	74	64.91
	Coding and robotic	5	100	23	46	12	20.34	40	35.09
Perception of benefit									
	Student benefit	8	16.67	20	24.69	38	44.19	66	30.7
	Professional benefit	14	29.17	25	30.86	27	31.4	66	30.7
	Personal benefit	13	27.08	29	35.8	11	12.79	53	24.65
	Context benefit	13	27.08	7	8.64	10	11.63	30	13.95
Strategy of the program									
	Conduct interdisciplinary studies	8	21.62	10	50	6	20	24	27.59
	Work with other disciplines	9	24.32	4	20	10	33.33	23	26.44
	Collaborative work environment	20	54.05	6	30	14	46.67	40	45.98
Total		125	19.17	225	34.36	306	46.47	652	100

**Note. In the table, the coding distribution of each subject according to the themes is given.*

3.4.1. Science teachers

ICT integration competencies and innovative approaches lead the expectations of science teachers from PD to meet their pedagogical knowledge needs. In terms of technological knowledge, expectations for developing ICT competencies outweighed expectations for coding and robotics. Science teachers want to participate in PD primarily to benefit their students, followed by the expectation of professional benefit. In terms of the design of the PD program, science teachers expect to a collaborative work environment.

3.4.2. Mathematics teachers

Half of the codes for mathematics teachers' expectations from PD related to pedagogical knowledge consisted of ICT integration competencies, with codes for other sub-themes being relatively less than the ICT integration competencies sub-theme. In terms of technological knowledge, expectations of mathematics teachers show a close distribution between ICT competencies and coding and robotics. The majority of expectations for benefits from the PD of mathematics teachers were personal benefit, followed by professional benefit. In terms of the design of the PD program, half of the codes related to conducting interdisciplinary studies.

3.4.3. CS teachers

Innovative approaches constituted half of the codes of CS teachers' expectations from PD related to their pedagogical knowledge needs. CS teachers have minimal (only five total codes) need to improve their technological knowledge. It can be argued that CS teachers consider themselves technologically competent. CS teachers codes for benefits from the PD were highest for professional benefit, but the codes related to professional, personal, and context benefit were close in terms of frequency. In terms of the design of the PD program, CS teachers expected a collaborative work environment.

4. Discussion and Conclusion

This study qualitatively examined the expectations of science, mathematics, and CS teachers from PD programs for integrated STEM education. The first research question was about teachers' pedagogical knowledge and technological knowledge expectations from a PD program related to integrated STEM. Four themes emerged regarding teachers' pedagogical expectations from an integrated STEM PD: (a) ICT integration competencies, (b) innovative approaches, (c) designing teaching process, and (d) designing learning process. First, teachers expect to increase and develop ICT integration competencies. To implement this, they want to mature their knowledge and skills towards innovative approaches, as well as learning to use this knowledge and skills to design the learning and teaching processes. Stohlmann et al. (2012) argue that content and pedagogical knowledge play a significant role in teaching self-efficacy. Therefore, it can be interpreted that teachers prioritize pedagogical knowledge to improve their self-efficacy perceptions about integrated STEM teaching. Kelley and Knowles (2016) draw attention to the need to base fundamental learning theories and pedagogical approaches in preparing STEM educators. In summary, it can be stated that the literature supports the findings of this study on pedagogical knowledge.

Teachers' expectations from integrated STEM PD in terms of technological knowledge emerged in two themes: *ICT competencies* and *coding and robotics*. Teachers' expectations of developing ICT competencies being more prevalent. Many kinds of technologies can be used in integrated STEM education, and technology stands out as the most challenging discipline to integrate into integrated STEM education (Wang et al., 2011). This study shows that teachers want to improve their technological knowledge, especially in coding and robotics. This finding may be due to the increased coding and robotic applications in STEM education in recent years. Indeed, The European Union (2020) policy "Shaping Europe's Digital Future" states that more than 90% of professional occupations today require digital competencies, including programming. In fact, the U.S. The Bureau of Labor Statistics (US-BLS) estimates that the top five growing STEM jobs will be CS, most of them in software development. The US-BLS estimates that more than 40% of new STEM jobs will be in software development alone, while concerning total jobs, more will be open in software development than all branches of traditional engineering combined (Adams, 2020). For these reasons, we can argue that integrated STEM education has evolved towards integrating STEM education with CS education. More importantly, the pedagogical knowledge expectations of teachers, who are the practitioner pioneers of integrated STEM education in schools, are prioritized when comparing technological expectations. Teachers expect their PD needs for integrated STEM education to be supported in pedagogical and technological knowledge. These expectations demonstrate their awareness of their needs for integrated STEM education. Therefore, we should focus on PD programs that will meet teachers' expectations.

The second research question was about how teachers expected to benefit from the PD program. Teachers' willingness to participate in a PD program related to integrated STEM education had four underlying benefit expectations: *student benefit, professional benefit, personal* *benefit,* and *context benefit*. Teachers want to benefit their students and their professional knowledge with PD. It has been reported in many studies in the literature that teachers have perceptions that STEM education is beneficial to their students (e.g., McMullin & Reeve, 2014; Park et al., 2017) and PD programs play an essential role in realizing this perceived benefit (Estapa & Tank, 2017; Ring et al., 2017). Therefore, the findings obtained in this study are crucial in terms of showing teachers' awareness of the benefits of supporting their PD related to integrated STEM.

The third research question of the study was about the design of the PD program. In the design of such programs, the most critical expectations of teachers was to provide collaborative working environments, thus increasing their opportunities to work with colleagues from different disciplines and their capacity to do interdisciplinary work. Although there is an emphasis on an interdisciplinary connection in STEM education, it is unclear how this will be achieved in the curriculum (Morrison et al., 2021). Therefore, teachers from different subjects must encounter opportunities to work collaboratively in PD programs. According to Song (2020), one of the essential teaching skills for integrated STEM education is applying team-teaching by cooperating with other subject teachers. Yet, few studies show how teachers work collaboratively to create or implement an integrated STEM curriculum (Balgopal, 2020). Furthermore, such training is newly emerging in the context of traditional teacher education programs. In order to rapidly implement integrated STEM education in schools, we must increase the competencies of our existing teachers. At this point, we need to question the PD needs of our teachers as well as analyzing and responding to their expectations .

The fourth research question was about how the teachers' expectations differed according to their subject area. As can be seen from the findings, the expectation priorities are different by subject. When the distribution of pedagogical expectations according to subject area was examined, PD expectations for science and mathematics teachers focused on integrating ICT into the learning and teaching process and for CS teachers the use of innovative approaches came to the fore. According to Smith et al. (2015), teachers had higher levels of self-confidence for the integration of mathematics and science but lower levels of self-confidence in teaching with technology and engineering. It is common for CS teachers to consider themselves competent in integrating technology into their learning and teaching processes. However, while the technological knowledge of computer teachers is higher than the other teachers, studies show that their content and pedagogical knowledge is not at a sufficient level (Sentance & Csizmadia, 2017; Yadav et al., 2016). This is in line with the expectations of CS teachers to learn more about innovative approaches.

When the expectations in terms of technological competencies were evaluated, it was seen that CS teachers did not attach much importance to this issue, whereas science teachers gave higher priority to ICT competencies. The expectations of mathematics teachers were more specific to coding and robotics. In addition to coding and robotics, various technologies such as animation, simulation, augmented/virtual reality are used in research and practice in science teaching (Özbek & Uslu, 2021). Therefore, it may seem natural for science teachers to develop their technological competencies in a much more comprehensive range. On the other hand, the expectations of mathematics teachers about coding and robotics were different. It can be interpreted that mathematics teachers attach more importance to associating mathematics subjects with coding and robotic applications. Coding and robotics are the application areas of CS education, and the idea that they should be a part of STEM education is becoming more and more common (Barr & Stephenson, 2011; Johnson et al., 2013; Sengupta et al., 2013; Shute et al., 2017), which is seen in the expectations of mathematics teachers for PD content.

When the distribution of benefit expectations according to the subject area was examined, it was seen that CS teachers prioritized professional benefits, mathematics teachers prioritized personal benefits, and science teachers prioritized student benefits. Ultimately, benefits are important considerations for PD designers to consider, as expectations of benefits will drive interest, motivation, and engagement in PD programs. When the expectations regarding the design of PD programs were examined, it was found that CS and science teachers gave priority to the collaborative working environment, and mathematics teachers emphasized interdisciplinary work. These findings indicate that CS and science teachers need collaborative group work in integrated STEM PD programs. Therefore, they search for collaboration among colleagues to develop their knowledge and skills for integrated STEM education. On the other hand, the need for interdisciplinary studies to develop the knowledge and skills of mathematics teachers to integrate STEM disciplines comes to the fore. From this point of view, environments where teachers can do collaborative work on STEM education, both for themselves and for other subject teachers, seem extremely valuable for these teachers. There are points where the expectations of CS, mathematics, and science teachers intersect and diverge and PD designers must consider these priorities for optimizing programs.

4.1. Implications

In this study, teachers' expectations from a PD program designed for integrated STEM education were revealed. Teachers seek to develop their competencies in CS-related topics such as coding and robotics, which are relatively new in integrated STEM education, as well as other ICT tools such as Web 2.0. Therefore, it is recommended that these teachers' expectations should be taken into account when organizing the content of PD programs. PD programs also need to be organized should to support classroom practices, so it is recommended to devote time to lesson or activity planning. These planning activities should allow teachers to work collaboratively with other teachers from different STEM disciplines as teachers want to benefit from their colleagues' knowledge, skills, and experience and be involved in the learning process together. Hence, it is suggested that integrated STEM PD programs adopt strategies in which science, mathematics, and CS teachers can collaboratively work and plan STEM learning and teaching processes. Indeed, ensuring a talented generation interested in STEM requires establishing teams of teachers working together with an integrated approach based on cross-curricular teaching and learning (Kurup et al., 2019). Also, collaboration and technology integration should be considered in increasing the effectiveness of STEM practices (Herro & Quigley, 2017).

However, it was also found that the expectations of teachers varied according to their subject area. So in addition to designing activities where different subject teachers work collaboratively, separate sessions with different content foci should be arranged for subject-specific requirements. In this context, since science and mathematics teachers prioritize their expectations about ICT integration competencies, it is recommended to plan PD programs to gain knowledge and skills about innovations in the field of instructional technologies. CS teachers, on the other hand, prioritize innovative pedagogies and collaboration. This expectation can be put to work in separate sessions with CS teachers.

4.2. Limitations and Recommendations

The findings obtained in this study reveal teachers' expectations for integrated STEM PD programs. However, the study has some limitations. A large group of participants from various provinces of Turkey participated in the research. Nevertheless, it should be considered that there may be differences in Turkey's STEM education policy, curricula, and PD of teachers compared to other countries. Therefore, future studies could focus on cross-cultural differences with the participation of teachers from various countries. In addition, the qualitative data were analyzed by content analysis. Thus, the results reached focus on describing the existing situation rather than generalizability. Future research may focus on the development of quantitative measurement tools based on the findings of this study. In the light of the data collected in quantitative ways, more general findings can be reached by examining teachers' expectations from PD programs for integrated STEM education. Also, future research may examine the underlying reasons why science teachers want to improve their knowledge and skills for ICT and ICT integration in the context of integrated STEM education. A study to be conducted with mathematics teachers in the future may focus on an in-depth examination of the reasons behind their desire to improve their knowledge and skills, especially in coding and robotics education, in the context of integrated STEM education. Finally, the role of technology in integrated STEM education can be examined within the framework of ICT integration models or CS education. In addition, the role of CS teachers in integrated STEM education also needs to be studied further.

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