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Research Article

Assessing chemistry teachers' needs and expectations from integrated STEM education professional developments

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Integrated Science, Technology, Engineering, and Mathematics (STEM) education has gained popularity worldwide. With the twenty-first century's different economic, political, and societal needs, nations intend to train citizens as better problem solvers. The current integrated STEM movement has influenced science curriculum documents and science teaching and learning to address those issues. To attain the goals of recent reform, teachers' understanding of the essential characteristics of integrated STEM education and learning implementation of the STEM activities with engineering design challenges are required. The related literature has stated that teachers' voices should be heard to address their needs through professional development (PD). In light of that point, in this needs assessment study, we intended to determine in-service chemistry teachers' expectations from and needs for implementing integrated STEM education. Data were collected from 112 chemistry teachers via open-ended questions. Results showed that most of the teachers stated that they expect to experience integrated STEM activities with their active participation through PDs. Additionally, the participants highlighted their expectations from a PD design to learn what integrated STEM education is and its essential features. Learning how to integrate STEM activities into lessons, developing integrated STEM lesson plans, and interdisciplinary chemistry teaching were other participants' expectations. Examples of participants' needs were learning implementation of integrated STEM education, integrating chemistry with STEM disciplines, finding chemistry-based STEM activities, and learning engineering design process and product. In order to reach PDs' goals set, first of all, teachers' needs for and expectations from the PDs should be determined regarding the STEM approach and then the PDs in which the teachers take a role as active participants should be organized.

Keywords: Integrated STEM education; Needs assessment; Professional development; In-service teachers; STEM training

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1. Introduction

With the release of the Next Generation Science Standards [NGSS] (2013), the view and way of science teaching have been shifted (Moore et al., 2015; Peterman et al., 2017). Among the motivations listed behind the transformation, to be the leader in the global economic competition,

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increase the number of students pursuing a career in Science, Technology, Engineering, and Mathematics (STEM) disciplines, educate learners who can solve daily-life problems, and train better engineers with the necessary qualifications were the most cited ones (Roehrig et al., 2012). To address the aforementioned issues, integrated STEM education has been on the agenda of education worldwide (Ekiz-Kiran & Aydin-Gunbatar, 2021). With the recent movement, engineering and engineering design processes are viewed as natural integrators of the STEM disciplines (Kelley & Knowles, 2016). Therefore, students are supposed to utilize scientific and math knowledge to solve an engineering problem and design a product or process (Capobianco & Rupp, 2014).

Although research has been revealed the effectiveness of the integrated STEM approach on students' science learning (Aydin-Gunbatar et al., 2018; Mathis et al., 2018) and conceptual science understanding (Apedoe et al., 2008), the development of twenty-first century skills (e.g., problem-solving, communication) (Brophy et al., 2008; Moore et al., 2015) and science process skills development (Gökbayrak & Karışan, 2017), teachers still have obstacles in implementing integrated STEM education. For instance, one of the most critical difficulties is the integration of different disciplines into the lesson (Guzey et al., 2014; Zhan et al., 2015). Teachers receive discipline-specific training (e.g. science); however, they are supposed to integrate other disciplines into their teaching (e.g. engineering) (Shernoff et al., 2017). Moreover, research has revealed that teachers have had problems using formative and authentic assessment techniques in integrated STEM activities (e.g., use of rubrics for evaluating the product designed, poster presentation, or assessing collaboration) (Teo & Ke, 2014). Limited resources, administrative problems, and separate classrooms for STEM subjects are other hindrances mentioned by teachers (Qablan, 2021). Given the obstacles listed, for the success of the integrated STEM movement, teachers' professional development (PD) is indispensable (Owens et al., 2018). At this point, matching the teachers' needs and training's focus is also central. In order to fully meet the teachers' needs, hearing teachers' voices about what their real needs are and which types of PDs they want to take are essential points (Owens et al., 2018). In light of that point, this study intended to determine in-service teachers' needs to implement integrated STEM education and their expectations from integrated STEM education PDs.

1.1. What is Integrated STEM Education?

Integrated STEM approach is required to address today's societal issues and solve daily life problems (Johnson, 2013). Roehrig et al. (2012) claim that integrating multiple STEM disciplines is necessary to solve these problems. In line with this argument, Moore et al. (2014) defined integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38). However, STEM education has historically been centered on developing science and mathematics as distinct disciplines, with minimal emphasis on technology or engineering (Kelley & Knowles, 2016). In addition, STEM content learning objectives can be concentrated on a single discipline, although the context for this content originates from another STEM discipline (Moore et al., 2014). From a different perspective, Kelley and Knowles (2016) conceptualized integrated STEM education as "the approach to teaching the STEM content of two or more STEM domains bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (p.3).

Compatible with the aforementioned integrated STEM definition, Moore et al. (2014) proposed a framework with six essential characteristics to develop an integrated STEM curriculum. First, the context provided for students should be engaging and motivating for successful STEM integration. They should be able to participate in the activity in an environment that is meaningful to them. Second, the activities students engage in should include engineering design challenges where students use relevant technologies to solve problems using their creativity and higher-order thinking skills. Third, the activity should provide a chance for learners to learn from failure and then redesign. Fourth, the primary objective of the activity should include science/mathematics content and some non-STEM disciplines for classroom learning to be relevant. Fifth, student-centred pedagogies (e.g. inquiry) for science/mathematics teaching should be implemented to assist students in developing science/mathematics knowledge. Finally, an effective integrated STEM curriculum should place a strong emphasis on collaboration and communication among students.

1.2. Definition and Important Characteristics of Effective PD

PDs can be defined as a range of activities and connections that may improve teachers' knowledge and ability (Desimone, 2009). Activities that can be included in PD programs are described by Paechter (1996) as "an activity in which the individual and the group interact to develop better models for practice which preserve the best of professional autonomy while promoting the sort of reflective culture that encourages constructive, cooperative change" (p.354). In line with these definitions, due to educational reforms, teachers require to pursue these reforms, which results in guidance need for successful implementation of the reforms (Borko, 2004). In addition to detailed definitions, the literature has provided essential characteristics of effective PD design, namely, content focus (Desimone, 2009; Loucks-Horsley et al., 2010), teachers' engagement into the activities learning as a learner (Desione, 2009; Owens et al. 2018), coherence among PD, school, district and state reforms and teachers' knowledge and belief (Banilower et al., 2007; Desimone, 2009), sufficient duration (Desimone, 2009), and collective participation of the participants (i.e., participation of teachers from the same school, grade or department) (Desimone, 2009). Furthermore, effective PDs reflect the instruction teachers are supposed to provide their students (Owens et al., 2018; Putnam & Borko, 1997).

1.3. Studies on Teachers' Perceptions of PD Needs

One way to support students to make meaningful connections across STEM disciplines is to receive support from a skillful and trained teacher (Qablan, 2021). Hence, teachers should be supported through effective PD programs to integrate STEM education into their instructions. At this point, research conducted to investigate teachers' perceptions and expectations of effective PDs is valuable. However, few studies have focused on teachers' expectations from an effective PDs and PD needs. Among those studies, some of them focused on teachers' general needs whereas others specifically focused on teachers' needs for and expectations from integrated STEM PDs.

Among the first group of research, Park Rogers et al. (2007) conducted qualitative research with 72 teachers and 23 PD facilitators. They compared science and mathematics teachers' and PD facilitators' views regarding aspects of effective PD. Teachers' views on effective PD were categorized as classroom application, teacher as a learner, and teacher networking. PD facilitators' views of effective PD were parallel with teachers' views. In addition, they also mentioned that effective PD should contribute teachers' content knowledge, pedagogical content knowledge (PCK) (i.e., which is described as knowledge discriminating a chemistry teacher from a chemist by Shulman (1986) and pedagogical knowledge. In another study conducted with in-service science teachers, Zhang et al. (2015) examined 118 K-12 in-service science teachers' needs for PD situated in specific science topics in life science, physics science, and earth science utilizing PCK framework. They compared and contrasted teachers' needs concerning teaching experience, grade level, and gender. They found that both elementary and secondary teachers need to improve their content knowledge on common science topics such as life science, physical science, and earth science. Further, this study found that teachers needed improvement in PCK components: knowledge of learners, instructional strategies, curriculum, and assessment. While teachers' needs did not differentiate based on gender, their needs distinguished according to teaching experience and the grade level that they teach. The authors found that novice teachers and elementary teachers perceived greater needs for improving content knowledge, knowledge of learner, curriculum and assessment than their experienced and secondary counterparts.

In the second group of the research focusing on teachers' need and expectations from integrated STEM education PDs, Shernoff et al. (2017) studied with 22 K-12 teachers and four administrations to identify specific challenges for and the needs for implementing the STEM approach. Results revealed that teachers feel inadequate and unprepared to implement the STEM education. Hence, teachers wanted to participate in integrated STEM education PDs, including collaboration among the participants, examples of effective integrated STEM lessons, and mentoring. Likewise, Owens et al. (2008) examined 800 elementary and secondary teachers' PD needs and preferences for STEM education in terms of PD format, duration and topics covered. Furthermore, the authors investigated how teachers' perceptions varied regarding district size, grade level, subject area and years of teaching experience. Results showed that teachers were generally interested in learning real-life applications, using educational technologies, and problem-based learning. Experienced teachers valued attending PDs for learning implementation of the STEM less than their inexperienced counterparts. They concluded that there should be a balance between what the literature suggests for effective PD and what teachers prefer to participate in. In the current study, due to the background of the researchers, science discipline was set as chemistry. We sought to investigate chemistry teachers' needs for STEM PDs and what they expect from integrated STEM education PDs by utilizing qualitative methodology. By doing so, we aimed to inform the literature regarding the chemistry teachers' needs and expectations from the STEM PDs, which is important due to the limited integrated STEM activities are included in chemistry as the science discipline (Aydın-Günbatar, 2018).

The research questions directing the study:

RQ 1) How do chemistry teachers' needs regarding STEM PDs vary by years of teaching experience, STEM PD experience and college degree level?

RQ 2) How do chemistry teachers' PD expectations from integrated STEM education PDs vary by years of teaching experience, STEM PD experience and college degree level?

2. Methodology

The current study is a needs assessment study defined as "the process of collecting information about an expressed or implied organizational need that could be met by conducting training" (Barbazette, 2006, p.5). In this study, to fulfill the purpose of identifying chemistry teachers' needs and expectations from integrated STEM education PDs, three steps of the needs assessment proposed by Barbazette (2006) were followed. These steps are gathering information, analyzing this information, and then creating a training plan. For this purpose, we first collected data from chemistry teachers and then analyzed it to understand their expectations and needs regarding STEM PDs. In the end, based on the analysis, we put forth the essential features of training prepared for teachers to help them develop a strong professional knowledge of integrated STEM education. Therefore, this study will provide the participants' expectations and needs from the integrated STEM PDs.

2.1. Participants of the Study

As stated above, due to the researchers' background, chemistry teachers were selected as the study group. The participants were the ones who applied for a week-long integrated STEM PD (the project number was 118B169). To be able to apply for the PD, the chemistry teachers were required to fulfill the form via Google Forms. In total, 112 in-service chemistry teachers, who were working in high schools in different cities all around Turkey, voluntarily participated in this study. The data collected from all applicants were used for the study. Convenient sampling was used for the participant selection (Fraenkel & Wallen, 2006). Among 112 teachers, 70 of them were female and 42 of them were male. Their ages ranged from 25 to 58. The distribution of the participants' ages is provided in Table 1.

Similar to Zhang et al.'s (2015) categorization for teachers' years of teaching experience, participants were divided into three categories based on their years of teaching experience:

beginning teachers (i.e., 0-5 years of teaching experience), established teachers (i.e., 6-10 years of teaching experience), and veteran teachers (i.e., more than 11 years of teaching experience). The vast majority of the participants had teaching experience of up to 5 years, provided in Table 2.

Table 1
The number of participants and their age intervals

Age interval	*Number of participants*
25-30	26
31-35	25
36-40	29
41-45	16
46-50	10
51+	6

Table 2
The number of participants and their year of teaching experience

Years of teaching experience	*Number of participants*
0-5 (Beginning)	48
6-10 (Established)	21
11+ (Veteran)	43

Focusing on the participants' college degree levels, they had three different degrees, which were bachelor's (BS) degree, master's (MS) degree and doctoral (PhD) degrees. 63 of the participants had BS degrees, while 46 of them had MS degrees in either chemistry or chemistry education. Only 3 of the participants had Ph.D. in chemistry education. Regarding the participants' participation in STEM PD, 20 teachers participated in STEM PDs previously, whereas 92 teachers did not participate in integrated STEM PDs. To provide confidentiality, codes (i.e., T-1, T-2, ... T-112) were given to the participants (Fraenkel & Wallen, 2006).

2.2. Data Collection

The data for the study were collected through two open-ended questions via Google Forms. In addition, teachers were asked to respond to the following questions:

- What topics do you need to develop to implement integrated STEM education? Please make a thorough explanation of your needs from integrated STEM PDs.
- What are your expectations from integrated STEM PDs? Please make a thorough explanation of your expectations.

The questions asked were prepared in light of the related literature (e.g., Friedrichsen et al. 2016; Park Rogers et al. 2007). Moreover, two experts, who are chemistry educators with Ph.D., were examined the questions and provided feedback. After expert opinion, the final version of the questions was prepared.

2.3. Data Analysis

The data were collected through Google Forms. All data were downloaded and coded in an iterative process. For the teachers’ expectations, first, two of the authors read the data and gained insights. In the second step, they formed the codes. The codes were created from the data, which was an inductive process (Patton, 2002). After the coding process, similar or related codes were put together to form categories. For example, ‘learning how to integrate engineering into chemistry’, ‘learning engineering and technology into chemistry’, etc. codes were put under ‘learning interdisciplinary chemistry teaching’ category. After forming categories, we formed themes for the categories in the later round, namely, integrated STEM related expectations, PCK related expectations, and other expectations (Table 3).

Table 3
Themes and categories formed through data analysis of the participants' PD expectations

Themes	*Categories*
Integrated STEM related expectations for PD design	Learning integrated STEM education and its essential features Experiencing integrated STEM activities, Interdisciplinary Chemistry teaching Developing integrated STEM lesson plan Learning how to integrate STEM activities into the classroom
PCK related expectations for PD design	Chemistry content knowledge Contemporary instructional strategies Lab activities Strategies for student use of educational technologies Aligning instruction with curriculum
Others	Social network Learning about project development

Similar coding steps were followed for the teachers' needs. Table 4 shows categories and themes for the needs that the participants stated.

Table 4
Themes and categories formed through data analysis of the participants' integrated STEM PD needs

Themes	*Categories*
Integrated STEM related needs	Integrating daily life applications chemistry related to chemistry topics into instruction Learning engineering design process and product To be able to propose STEM-based projects Finding chemistry-based STEM activities Learning implementation of integrated STEM education Integrating chemistry with STEM disciplines Developing a STEM lesson plan
PCK related needs	Chemistry content knowledge Chemistry-based lab activities Using educational technology to support chemistry teaching
Other needs	Attract students' attention

In the data analysis, as mentioned above, two researchers analyzed the whole data. Minor disagreements were resolved through discussion between the two researchers. The whole data analysis was conducted with consensus.

In the final step, to establish trends for years of teaching experience, STEM PD experience, and college degree level, we determined the number of teachers for each category and calculated the frequencies for each group. For example, to examine to what extent beginning, established or veteran teachers' needs for PDs for integrated STEM implementation are similar or different, we presented the results for teachers with different years of teaching experience. One participant's needs for STEM PD were coded utilizing more than one code if necessary. For example, in some cases, participants' explanation includes experiencing integrated STEM activities as a learner and integrating STEM disciplines into chemistry teaching. To preserve the confidentiality of the participants, their names were not used in this study.

3. Results

The results were organized in two sections. The first section includes aspects that chemistry teachers need to develop regarding integrated STEM education with PD support. The second section includes chemistry teachers' expectations from integrated STEM education PDs. Within scope of this study, chemistry teachers' integrated STEM-related needs and expectations from STEM PDs were presented in this part. PCK-related and other needs and expectations were not covered.

3.1. Chemistry Teachers' Needs to be developed regarding Integrated STEM Education with PD Support

Chemistry teachers mentioned several points that they need to develop related to integrated STEM education with PD support. They primarily need integrated STEM education to implement, finding chemistry-based integrated STEM activities, and interdisciplinary chemistry teaching. On the other hand, they need less support regarding integrating daily life applications of chemistry into instruction and developing an integrated STEM lesson plan (Table 5).

Chemistry teachers most frequently need support to implement integrated STEM education, integrate chemistry with other STEM disciplines, and find chemistry-based integrated STEM activities during their instruction. Especially, beginning and veteran teachers indicated greater need to learn implementation of integrated STEM education than did established teachers. In terms of college education level and STEM PD experience, there was no remarkable difference among teachers. A veteran teacher, T70 stated his need regarding implementation of integrated STEM education as: "I need to learn how to utilize integrated STEM activities during chemistry teaching". Regarding another point that chemistry teachers' need to develop was integrating chemistry with other STEM disciplines. Teachers who had STEM PD experience and MS or PhD degrees indicated more need for integrating chemistry with engineering, technology and mathematics than their counterparts. For instance, T109, who had STEM PD experience, stated, "I would like to learn how to integrate technology and engineering into my chemistry lesson". Similarly, T51, who had an MS degree, mentioned, "We have already known mathematics discipline, but I don't know in what way we should integrate technology, engineering, and software programs into chemistry teaching". In terms of years of teaching experience, there was no difference that deserves attention. Furthermore, chemistry teachers need support to find chemistry-based integrated STEM activities. Veteran teachers perceived greater needs to find chemistry-based integrated STEM activities than their less experienced counterparts. In addition, based on percentages, chemistry teachers who attended a STEM PD indicated a greater need to find chemistry-based integrated STEM activities than teachers who had no STEM PD experience. Regarding college education level, there was no remarkable difference among teachers. The following expression represented chemistry teachers' needs for implementing integrated STEM: T71, who had an MS degree, stated "I had difficulty in finding chemistry-based problems from the STEM education perspective, for instance, designing a product for recycling and waste management". Also, T100, who had STEM PD experience, mentioned the topics she needed support as "Application of real-life problems related to chemistry during integrated STEM education to improve students' cognitive level, example of integrating technology and chemistry". Regarding proposing a STEM-based project, chemistry teachers who had no STEM PD experience and had a BS degree indicated greater need for learning to propose a STEM-based project than their counterparts. For instance, T49, who had BS degree and no STEM PD experience, stated "I need to learn how to propose a STEM-based project using technology". Finally, chemistry teachers who had STEM PD experience and MS or PhD education level indicated more need for learning

Table 5

Frequency of integrated STEM-related needs of teachers depending on their years of teaching experience, STEM PD experience, and college degree levels

	Years of experience			*STEM PD experience*		*College degree level*		*Total*
	0-5 years N= 48	6-11 years N=22	Over 11 years N= 42	Yes N=20	No N= 92	BS N=63	MS & PhD N= 49	N= 112 Chemistry teachers
Integrated STEM-related needs								
Learning implementation of integrated STEM education	N= 11 (23%)	N= 2 (9%)	N= 15 (36%)	N= 4 (20%)	N= 24 (26%)	N= 15 (24%)	N= 13 (27%)	N= 28 (25%)
Integrating chemistry with other STEM disciplines	N= 7 (15%)	N=3 (14%)	N=8 (19%)	N= 5 (25%)	N= 13 (14%)	N=8 (13%)	N=10 (20%)	N= 18 (16%)
Finding chemistry-based integrated STEM activities	N=4 (8%)	N=4 (18%)	N=10 (24%)	N=6 (30%)	N= 12 (13%)	N= 12 (19%)	N= 6 (12%)	N= 18 (16%)
To be able to propose STEM-based projects	N=5 (10%)	N=3 (13%)	N=3 (7%)	N= 0	N= 11 (12%)	N= 9 (14%)	N=2 (4%)	N= 11 (9%)
Learning engineering design process and product	N=2 (4%)	N=2 (9%)	N=4 (10%)	N= 0	N= 8 (9%)	N= 2 (3%)	N= 6 (12%)	N= 8 (7%)
Integrating daily life applications of chemistry into instruction	N=2 (4%)	N=1 (5%)	N=0	N= 0	N= 3 (3%)	N=1 (2%)	N=2 (4%)	N=3 (3%)
Develop an integrated STEM lesson plan	N=2 (4%)	N=0	N=0	N= 1 (5%)	N= 1 (1%)	N=1 (2%)	N=1 (2%)	N=2 (2%)

engineering design process and product than their counterparts. For instance, a teacher who had both master's degree and STEM PD experience stated her needs to learn engineering design process which is one of the essential features of integrated STEM education as: "I need to learn how to propose STEM based projects and design a product utilizing engineering design process and integrating STEM disciplines" (T50).

3.2. Chemistry teachers' expectations from integrated STEM education PDs

The following part includes the most frequently mentioned expectations of the participants from an integrated STEM PD. According to the results, teachers stated STEM-related expectations from PDs which included experiencing integrated STEM activities as a learner, learning what integrated STEM education is and its essential features, integrating chemistry into other STEM disciplines (mathematics, technology, and engineering), learning integration of integrated STEM education into the class, and developing an integrated STEM lesson plan. Table 6 indicates the participants' STEM-related expectations and frequency and percentage of the categories according to the participants' years of teaching experience, STEM PD experience, and college degree levels.

As seen in Table 6, most of the teachers' expectations from STEM PD is experiencing STEM activities in a manner similar to students and see examples of STEM lessons (51 of 112, or 46%). Compared to years of experience, veteran teachers (> 11 years) indicated more need to participate in STEM activities as learners than their less experienced counterparts. For example, the following expression represented a veteran chemistry teacher's expectation from an integrated STEM education PD: "In addition to theoretical knowledge about integrated STEM education, I expect to see examples of integrated STEM activities that we can use in our lessons. Also, I expect to get training to develop integrated STEM activities" (T89). In addition, based on percentages, chemistry teachers who attended a STEM PD indicated a greater expectation to experience STEM activities than did teachers who had no STEM PD experience. In addition, it was found that there was no remarkable difference in teachers' PD expectations considering graduate level.

Overall, one of the most frequent points identified was learning integrated STEM education and its essential features (46 of 112, or 41%). In this category, chemistry teachers mainly mentioned their expectations to learn about integrated STEM education and its features such as engineering designs process and using real-world problems. In terms of years of experience, beginning (< 6 years of teaching experience) and established (6-11 years of teaching experience), teachers were more eager to learn integrated STEM education than veteran teachers (over 11 years of teaching experience). However, there were no remarkable differences among teachers in terms of STEM PD experience and college degree level. The following quotations were representative of beginning and established chemistry teachers' expectations from integrated STEM PD:

> I'm a chemistry teacher. I would like to learn and teach how chemistry is used in everyday life and apply this knowledge to integrated STEM activities during the PD program. After this program, I would like to implement these activities with my students. (T35, beginning teacher)
>
> What is integrated STEM education? Applications of integrated STEM education all over the world? How can I integrate STEM disciplines into my lessons? What are the main features of integrated STEM education? What is the role of students and teachers during integrated STEM education? I would like to find answers to these questions and see examples of effective integrated STEM lessons. (T51, established teacher)

Chemistry teachers are expected to learn how to integrate chemistry with other STEM disciplines, namely engineering, mathematics and technology. Veteran teachers indicated more importance on interdisciplinary chemistry teaching than their less experienced counterparts. Also, they emphasized the importance of working in a group comprised of teachers from other disciplines. He stated that "I need to observe effective integrated STEM lessons, and if possible, I would like to work with teachers from other disciplines to learn interdisciplinary teaching effectively." (T71). Also, another teacher mentioned her expectation from integrated STEM PD

Table 6
Frequency of integrated STEM-related expectations of teachers for PD design depending on years of teaching experience, STEM PD experience and college degree levels

	Years of experience			*STEM PD experience*		*College degree level*		*Total*
	0-5 years N= 48	6-11 years N=22	Over 11 years N= 42	Yes N=20	No N= 92	BS N=63	MS & PhD N= 49	N= 112 Chemistry teachers
Integrated STEM-related expectations for PD design								
Experiencing STEM activities	17 (35%)	10 (46%)	24 (57%)	12 (60%)	39 (42%)	27 (43%)	24 (49%)	N= 51 (46%)
Learning integrated STEM education and its essential features	24 (50%)	10 (46%)	12 (29%)	9 (45%)	37 (40%)	25 (40%)	21 (43%)	N= 46 (41%)
Interdisciplinary chemistry teaching	6 (13%)	4 (18%)	9 (21%)	3 (15%)	16 (17%)	9 (14%)	10 (20%)	N= 19 (17%)
Learning how to integrate STEM activities into the class	2 (4%)	4 (18%)	5 (12%)	4 (20%)	7 (8%)	3 (5%)	8 (16%)	N= 11 (10%)
Development a STEM lesson plan	2 (4%)	2 (9%)	4 (10%)	4 (20%)	4 (4%)	3 (5%)	5 (10%)	N= 8 (7%)

as integrating technology into chemistry teaching. She mentioned "I would like to implement integrated STEM education in my lessons effectively, so I need to learn educational technologies to enrich integrated STEM activities that I developed and use in my lessons." (T72) In addition, regarding STEM PD experience, there is no big difference in teachers' expectations. However, considering college education level, teachers who took graduate education indicated greater expectations for integrating other disciplines into chemistry teaching than did other teachers. For instance, T84 stated his expectations from the STEM PD program as:

> I have already known that science, technology, mathematics, and engineering were integrated. However, I don't feel confident in designing an integrated STEM-based chemistry lesson and utilizing STEM disciplines, especially technology and engineering, while planning my lessons. Also, I don't think I received training related to interdisciplinary chemistry teaching during my teacher education program. If I learn how to integrate these disciplines, I could effectively use integrated STEM education in my lessons.

Another point is that teachers had difficulty in implementing integrated STEM education in their classes due to a lack of knowledge regarding integrating STEM activities into chemistry teaching. Established teachers with 5-11 years of teaching experience indicated greater expectation from STEM PD for improving their knowledge of integrating STEM activities into the classroom than the beginning and veteran teachers. One of the established teachers mentioned her need as: "I would like to learn integrated STEM education and how to integrate STEM activities into my teaching. In this way, I would lead students to participate actively in these" (T59). Regarding STEM PD experience, teachers who participated in another STEM PD reported greater expectations to implement integrated STEM education during their lessons. T44 mentioned her expectations from STEM PD as: "I would like to learn both theoretical knowledge and practical knowledge pertained to integrated STEM education. The PD program should include integrated STEM activities that we can apply during our lessons." In terms of college education level, teachers who had graduate education differed from their counterparts in terms of expectation to learn how to integrate STEM-based activities during chemistry teaching. The following quotation was representative of chemistry teachers' expectation from STEM PD: "I would like to learn integrated STEM education and how to use it in chemistry teaching. My expectation from the PD program is to learn applicable integrated STEM activities that attract students' attention during my lessons." (T96) "I would like to learn [STEM] activities and how to integrate these activities into my classes." (T85)

Finally, teachers expected to learn how to develop an integrated STEM lesson plan during the PD program. Especially, established and veteran teachers have a greater expectation for developing a lesson plan than beginning teachers do. For instance, a veteran teacher stated that: "During PD, we [participants of the PD] can work in groups to develop an integrated STEM lesson plan compatible with different grade levels and evaluate these plans among groups would be effective, so we would see effective lesson plan examples." (T77) In terms of STEM PD experience, teachers who had previously participated in STEM PD, had a greater expectation for developing an integrated STEM lesson plan than did other teachers. Also, teachers who had a master's or doctoral degree had a greater expectation for developing integrated STEM lesson plans for their instructions than teachers who had bachelor's degree. For instance, a teacher who had both master's degree and STEM PD experience stated her expectations from the PD program as:

> I would like to learn how to integrate STEM education and chemistry into my lesson plans. By this way, I want to learn how to increase my students' skills and abilities such as creativity, critical thinking, and cooperation while learning chemistry. (T28)

4. Discussion

With the recent integrated STEM education reform, teachers' need for learning, implementing and planning STEM activities should be carried out if the STEM is moved beyond a slogan (Bybee, 2010). However, research has revealed that "teachers have a limited understanding of what STEM is and what it means for their instruction" (Dare et al., 2019, p. 1702). Hence, before providing PDs, teachers' specific needs and expectations should be asked, and then the effective PDs directly addressing the needs and expectations determined should be offered. In line with that point, in this research 112 chemistry teachers' (i.e., teaching chemistry in high school grades 9-12) PD needs for implementing integrated STEM education and teachers' expectations from STEM PDs were focused on. Regarding the first research question, results indicated that chemistry teachers mostly needed to learn implementation of integrated STEM education, integrating chemistry with other STEM disciplines, and finding chemistry-based integrated STEM activities. Considering the second research question, results showed that in-service chemistry teachers mostly expected to experience applications of the integrated STEM activities as an adult learner (i.e., active participation), learn essential characteristics of the approach, and learn interdisciplinary chemistry teaching. The results would be discussed in light of the related literature and implications would be provided for PD developers. To impede redundancy, common needs and expectation would be discussed together.

First of all, most of the participants both needed and expected to learn about integrated STEM education and the essential features of the approach. That need and expectation is parallel with the previous research stating that teachers' limited knowledge of integrated STEM education and its essential aspects (e.g., Dare et al., 2019; Lau & Multani, 2018; Shernoff et al., 2017). Given the fact that the teachers received discipline-specific training through pre-service teacher education programs, they are not familiar with integrating other disciplines into their teaching (Shernoff et al., 2017). Regarding the features of integrated STEM education, the participants mentioned their needs for learning engineering and engineering design process, which is parallel to the points revealed by the previous studies (e.g., Guzey et al. 2014; Stohlmann et al. 2012). The possible explanation behind that need is that although teachers took science, mathematics, and technology courses through K-12 and pre-service education programs, most of them have not met engineering and design process. Hence, to address that need, introduction to engineering and design process elective course can be offered by pre-service teacher education programs to future teachers. Additionally, PDs may include more engineering and design process aspects for in-service teachers. Another essential characteristic of the integrated STEM approach was indicated both as a need and expectation from PDs by the participants was "use of chemistry-related real-world problems". That specific need and expectation may stem from the limited number of integrated STEM activities, including chemistry as the science discipline (Aydın-Günbatar, 2018). When compared to physics, chemistry knowledge and daily-life applications of chemistry have been less focused. Hence, chemistry teachers most probably need to learn chemistry-based integrated STEM activities that address real-world problems. To address this point, chemistry educators, chemists, and chemical engineers should work together to design chemistry-related STEM activities for teachers' use.

Depending on the current research results, participant teachers mostly expected to experience applications of the integrated STEM activities as adult learners during the STEM PD programs. In this study, especially veteran teachers highlighted expectations for engagement in learning how to apply integrated STEM activities. Veteran teachers may have doubts about teaching integrated STEM activities due to their inadequate integrated STEM knowledge, resulting in a lack of confidence in implementing these activities. Another possible explanation for the result may be that beginning teachers may take integrated STEM or interdisciplinary courses during pre-service teacher education. With the release of NGSS in 2013, integrated STEM courses have been more common in pre-service teacher education programs. Another reason for teachers' expectation to engage in integrated STEM activities may be learning to direct students. Teachers attributed great importance to involving in integrated STEM activities and emphasized that students need to engage in these activities for their academic success and motivation (Margot & Kettler, 2019). Therefore, teachers may need to learn how to act during an integrated STEM activity to help their students during the activity. Finally, applying activities is one of the responsibilities that a STEM teacher is supposed to accomplish. Without connecting theory and practice during an integrated STEM lesson, teachers fail to properly apply integrated STEM activities, which may mean that the activity cannot go beyond a simple hands-on activity with design steps (El Nagdi et al., 2018).

Therefore, teachers may need and expect support in applying integrated STEM activities to learn how to integrate theory and practice into each other. Hence, PDs including more implementation of the integrated STEM activities and providing active participation to teachers should be organized by PD providers. Moreover, those PDs may provide more space for veteran teachers with very limited knowledge and experience of integrated STEM education and its implication.

Yet another essential expectation that deserves attention was to learn interdisciplinary chemistry teaching during STEM PDs. Especially veteran teachers indicated greater expectations than their counterparts. A possible reason of the observed difference may be that although veteran teachers were generally familiar with their subject, they were not familiar with other disciplines of STEM (e.g., technology and engineering). Therefore, they may expect to learn interdisciplinary chemistry teaching through the PDs. With the help of the PD support, teachers would learn how to connect the disciplines, integrate them into their teaching (Stohlmann et al., 2012). Regarding developing an integrated STEM lesson plan and learning how to integrate STEM activities into their instruction, teachers with STEM PD experience and master or Ph.D. degrees indicated greater expectations from STEM PDs than their counterparts. Those teachers most probably may gain awareness and experience related to integrated STEM education previously so their expectations from STEM PDs moved beyond learning essential features of integrated STEM education to develop integrated STEM lesson plans. That point provides motivating evidence for the organization of integrated STEM PDs for teachers.

To conclude, this needs assessment study focused on chemistry teachers' real needs and expectations from the integrated STEM PDs. Results were also compared and contrasted regarding teaching experience, integrated STEM PD experience, and college degree levels of the teachers. One of the limitations of the study is collecting data only from chemistry in-service teachers. Another limitation is the lack of interviews that may provide detailed explanations behind teachers' needs and expectations. Despite the limitations, the researchers worked with in-service teachers in this study and collected data from a large group of chemistry teachers working all around Turkey.

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References

Apedoe, X. S., Reynolds, B., Ellefson, M. R., & Schunn, C. D. (2008). Bringing engineering design into high school science classrooms: the heating/cooling unit. *Journal of Science Education and Technology, 17*(5), 454–465. https://doi.org.10.1007/s10956-008-9114-6

Aydin-Gunbatar, S., Tarkin-Celikkiran, A., Kutucu, E. S., & Ekiz-Kiran, B. (2018). The influence of a design-based elective STEM course on pre-service chemistry teachers' content knowledge, STEM conceptions, and engineering views. *Chemistry Education Research and Practice, 19*(3), 954-972. https://doi.org/10.1039/C8RP00128F

Aydın-Günbatar, S. (2018). Designing a process to prevent apple's browning: A STEM activity. *Journal of Inquiry Based Activities, 8*(2), 99-110.

Banilower, E. R., Heck, D. J., & Weiss, I. R. (2007). Can professional development make the vision of the standards a reality? The impact of the national science foundation's local systemic change through teacher enhancement initiative. *Journal of Research in Science Teaching*, *44*, 375–395. https://doi.org/10.1002/tea.20145

Barbazette, J. (2006). *Training Needs Assessment: Methods, Tools, and Techniques*. Pfeiffer Publishing.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3-15. https://doi.org/10.3102/0013189X033008003

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*, 369–387. https://doi.org/10.1002/j.2168-9830.2008.tb00985.x

Bybee, R. W. (2010). What is STEM education?. *Science, 329,* 996. https://doi.org/10.1126/science.1194998

Capobianco, B. M., & Rupp, M. (2014). STEM teachers' planned and enacted attempts at implementing engineering design-based instruction. *School Science and Mathematics*, *114*(6), 258-270. https://doi.org/10.1111/ssm.12078

Dare, E. A., Ring-Whalen, E. A., & Roehrig, G. H. (2019). Creating a continuum of STEM models: Exploring how K-12 science teachers conceptualize STEM education. *International Journal of Science Education*, *41*(12), 1701-1720. https://doi.org/10.1080/09500693.2019.1638531

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199. https://doi.org/10.3102/0013189X08331140

Ekiz-Kiran, B., Aydin-Gunbatar, S. (2021). Analysis of engineering elements of K-12 science standards in seven countries engaged in STEM education reform. *Science & Education, 30*, 849-882. https://doi.org/10.1007/s11191-021-00227-w

El Nagdi, M., Leammukda, F., & Roehrig, G. (2018). Developing identities of STEM teachers at emerging STEM schools. *International Journal of STEM Education*, *5*(1), 1-13. https://doi.org/10.1186/s40594-018-0136-1

Fraenkel J. R. & Wallen N. E., (2006). *How to design and evaluate research in education*. McGraw-Hill.

Friedrichsen, P. J., Linke, N., & Barnett, E. (2016). Biology teachers' professional development needs for teaching evolution. *Science Educator*, *25*(1), 51-61.

Gökbayrak, S., & Karışan, D. (2017). An Investigation of the Effects of STEM based Activities on Preservice science Teacher's Science Process Skills. *Western Anatolia Journal of Educational Sciences, 8(2),* 63-84. https://doi.org/10.14687/jhs.v14i4.5017

Guzey, S. S., Tank, K., Wang, H. H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3–6 for implementing engineering into classrooms. *School Science and Mathematics*, *114*(3), 139-149. https://doi.org/10.1111/ssm.12061

Johnson, C. C. (2013). Conceptualizing integrated STEM education. *School Science and Mathematics, 113*(8), 367–368. https://doi.org/10.1111/ssm.12043

Kelley, T. R. & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(11), 1-11. https://doi.org/10.1186/s40594-016-0046-z

Lau, M., & Multani, S. (2018). Engineering STEM teacher learning: Using a museum-based field experience to foster STEM teachers' pedagogical content knowledge for engineering. In Uzzo, S. M., Graves, S. B., Shay, E., Harford, M., & Thompson, R. (Eds.), *Pedagogical content knowledge in STEM: Research to practice* (pp. 195-213). Springer.

Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S., & Hewson, P. (2010). *Designing professional development for teachers of science and mathematics*. Corwin Press

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, *6*(1), 1-16. https://doi.org/10.1186/s40594-018-0151-2

Mathis, C. A., Siverling, E. A., Moore, T. J., Douglas, K. A., & Guzey, S. S. (2018). Supporting engineering design ideas with science and mathematics: A case study of middle school life science students. *International Journal of Education in Mathematics, Science and Technology (IJEMST)*, *6*(4), 424-442. https://doi.org/10.18404/ijemst.440343

Moore, T., Stohlmann, M., Wang, H., Tank, K., Glancy, A., & Roehrig, G. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardella (Eds.), *Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices* (pp. 35–60). Purdue University Press.

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). NGSS and the landscape of engineering in K-12 state science standards. *Journal of Research in Science Teaching*, *52*(3), 296-318. https://doi.org/10.1002/tea.21199

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* The National Academies Press.

Owens, D. C., Sadler, T. D., Murakami, C. D., & Tsai, C. L. (2018). Teachers' views on and preferences for meeting their professional development needs in STEM. *School Science and Mathematics*, *118*(8), 370-384. https://doi.org.10.1111/ssm.12306

Paechter, C. (1996). What do we mean by professional development? *Research in Post-Compulsory Education*, *1*(3), 345-355. https://doi.org/10.1080/1359674960010305

Park Rogers, M., Abell, S., Lannin, J., Wang, C. Y., Musikul, K., Barker, D., & Dingman, S. (2007). Effective professional development in science and mathematics education: Teachers' and facilitators' views. *International Journal of Science and Mathematics Education*, *5*, 507–532. https://doi.org/10.1007/s10763-006-9053-8

Patton, M. Q. (2002). *Qualitative research and evaluation methods.* Sage.

Peterman, K., Daugherty, J. L., Custer, R., & Ross, J. (2017). Analysing the integration of engineering in science lessons with the Engineering-Infused Lesson Rubric. *International Journal of Science Education, 39* (14), 1913-1931. https://doi.org/10.1080/09500693.2017.1359431

Putnam, R. T., & Borko, H. (1997). Teacher learning: Implications of the new view of cognition. In B. J. Biddle, T. L. Good, & I. F. Goodson (Eds.), *The international handbook of teachers and teaching* (pp. 1223-1296). Kluwer.

Qablan, A. (2021). Assessing teachers education and professional development needs to implement stem after participating in an intensive summer professional development program. *Journal of STEM Education: Innovations and Research*, *22*(2), 75-79.

Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics*, *112*(1), 31-44. https://doi.org/10.1111/j.1949-8594.2011.00112.x

Shernoff D. J., Sinha S., Bressler D. M., & Ginsburg L., (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education, 4(13),* 1–16, https://doi.org/10.1186/s40594-017- 0068-1

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14. https://doi.org/10.3102/0013189X015002004

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *2*(1), 4. https://doi.org/10.5703/1288284314653

Teo, T. W., & Ke, K. J. (2014). Challenges in STEM teaching: Implication for preservice and inservice teacher education program. *Theory into Practice, 53*(1), 18–24. https://doi.org/10.1080/00405841.2014.862116

Zhang, M., Parker, J., Koehler, M. J., & Eberhardt, J. (2015). Understanding inservice science teachers' needs for professional development. *Journal of Science Teacher Education, 26,* 471–496. https://doi.org/10.1007/s10972-015-9433-4