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TEACHERS' PERCEPTIONS AND STEM TEACHING ACTIVITIES: ONLINE TEACHER PROFESSIONAL DEVELOPMENT AND EMPLOYMENT

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Abstract. *This study addressed teachers' perceptions of the effect of online teacher professional development programs (OTPDPs) on their professional development. This five-month study focused on four aspects of OTPDPs: (1) Teachers' perceptions on OTPDPs, (2) the impact of OTPDPs on lesson planning, (3) the impact of OTPDPs on STEM teaching, and (4) the impact of OTPDPs in STEM education on teacher employment. The sample consisted of 36 teachers. An OTPDP tailored to STEM education was designed to help participants develop professional skills. This study adopted a qualitative type of research, which was a single case study." Data were collected through interviews, videotapes, and lesson plans. The data were analyzed using content analysis. Participants had positive perceptions about OTPDPs. They stated that the OTPDP helped them plan and teach STEM better and gain pedagogical and content knowledge. It also allowed them to acquire technological self-efficacy. They also noted that OTPDPs helped teachers develop the skills that would make them more likely to be employed in the future. The results indicate that technological self-efficacy and Internet access are of paramount importance for effective OTPDPs.*

Keywords: *online professional development, STEM education, teacher perception*

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Introduction

Advances in science and technology have paved the way for integrating information and communication technologies (ICT) into education (Yıldırım, 2020a). This integration has also changed the way the business world operates and the qualities companies seek in their employees. Every new generation has to work harder than the previous one. This indicates the close relationship between STEM education and teacher employment, an essential outcome of education. Generation Z, born into technology, wants to see social learning tools being used in education, raising questions over the effectiveness of conventional teaching and bringing teachers face to face with new learning environments (Alvarez et al., 2009). These developments leave teachers no choice but to improve themselves professionally. Teachers with professional skills lead innovations and developments and make a difference in students' learning (İlgan, 2013). However, teachers are deprived of time, quality education, and appropriate learning environments to develop those skills (Blanchard et al., 2016). Moreover, many professional development programs (PDPs) are only theory-based programs that are not tailored to students' and teachers' needs, hindering professional development (Cohen & Hill, 2000). Therefore, teachers need flexible, cheap, and high-quality online teacher professional development programs (OTPDPs) (Powell & Bodur, 2019). OTPDPs can help teachers develop professional skills anywhere and anytime as long as they are well-planned and applicable (Vrasidas & Zembylas, 2004). If not, they may not yield the desired learning and teaching outcomes (Parson et al., 2019).

Research shows that well-planned online learning environments are effective (Dash et al., 2012; Powell & Bodur, 2019; Sheridan & Wen, 2021). Moreover, well-designed OTPDPs provide powerful learning (Darling-Hammond et al., 2017; Healy et al., (2020) and change teachers' attitudes from negative to positive with high motivation and satisfaction (Walsh et al., 2020). Therefore, teachers should be provided with long-term and interactive OTPDPs based on cooperation and multi-disciplinarity. Reforms have been undertaken worldwide to help teachers improve themselves professionally (OECD, 2005). However, OTPDPs are far from enough, which is an obstacle in the path of professional development (Darling-Hammond et al., 2017; Parson et al., 2019; Schachter et al., 2019; Sheridan & Wen, 2021). Online learning

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can help overcome those obstacles (Nese et al., 2020). More OTPDPs are needed because students' learning and academic performance depend on teachers' professional skills (Powell & Bodur, 2019).

Research Originality

Only few studies address OTPDPs in STEM education (Dede et al., 2016). Most studies on OTPDPs adopted quantitative research designs (Parson et al., 2019; Powell & Bodur, 2019). What is more, qualitative studies do not examine the effects of OTPDPs in detail, thereby failing to provide a more contextualized picture required to design effective OTPDPs (Dede et al., 2009). This study addressed teachers' perceptions, lesson plans, and videos to make a detailed contextual analysis of OTPDPs. Most studies do not specify any design principles and standards required for effective OPDs (Bragg et al., 2021). However, this study specified design principles and standards for OTPDPs and put them to use, and also focused on non-personnel program resources (videos, interactive learning environments, etc.), which have been understudied so far (Bragg et al., 2021). This study also incorporated different design elements, such as flexibility, support, interactive learning environments, reading resources, and microteaching.

Research Significance

An OTPDP for teachers was designed and implemented. Another significance of this study was that the OTPDP was closely associated with the labor market components. The program aimed to increase their STEM competence because they are interested in learning STEM education and putting it into practice in their lectures (Goodnough et al., 2014). However, teachers have limited opportunities to have a sound grasp of STEM education (Stohlman et al., 2012). There are only a few OTPDPs tailored to STEM education, but teachers cannot enroll in them because they are held during the semester. In other words, teachers are deprived of training in STEM education (Ejiwale, 2013; Ring et al., 2017). Moreover, those with little knowledge of STEM education are more likely to have negative attitudes towards it (Hackman et al., 2021). Therefore, teachers can use OTPDPs to develop professional skills regarding STEM education. However, there is little research on this topic (Dede et al., 2016). This is the first study to address the potential of OTPDPs tailored to STEM education

Aim of Research and Questions

The aim of this study was to identify some aspects of the effect of OTPDPs on teachers' professional competence and STEM teaching performance. In the present study, an OTPDP was administered to participants for STEM education. Participants planned lessons and presented them. They also worked in groups and performed microteaching through STEM education. Afterward, they were interviewed. In this context, the research questions were as follows:

1. What do teachers think about OTPDPs?
2. How do OTPDPs reflect on STEM lesson planning?
3. How do OTPDPs reflect on STEM teaching?
4. How do OTPDPs in STEM education reflect on teacher employment?

Literature Review

Online Teacher Professional Development Program (OTPDP)

OTPDPs comprise online courses, group work, interactive learning modules, and workshops (Ross, 2011). Teachers can access OTPDPs anywhere and anytime and improve themselves professionally (Southern Regional Education Board [SREB], 2004; Heap et al., 2020). OTPDPs provide teachers with content knowledge and interactive learning and discussion environments (Bragg et al., 2021; Jamil & Hamre, 2018). Teachers who interact are more likely to share knowledge and experience and work together to achieve shared goals (Lee et al., 2020; Reeves & Pedulla, 2013). Therefore, OTPDPs should be well-planned in line with the criteria/standards laid down by the guides in the literature (International Association for K-12 Online Learning [INACOL], 2011; International Society for Technology in Education [ISTE], 2008; Office of Educational Technology [OET], 2014; SREB, 2004). These criteria/standards are (1) identifying needs, (2) interaction and collaboration, (3) usefulness, (4) realistic and applicable activities, (5) reflection, and (6) technological and disciplinary integration.

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Creating an Effective Professional Development Program

Well-designed and effective OTPDPs are long-term and domain-specific (Harris & Sass, 2011). Although most OTPDPs are well designed, they are far from meeting teachers' PD needs because they are too short in duration (Birman et al., 2000; Rinke et al., 2016). An OTPDP should be at least 80 hours and support classroom activities (Johnson & Fargo, 2010; Supovitz & Turner, 2000). For example, Vrasidas and Zembylas (2004) stated that OTPDPs should include practical classroom tasks and activities. Farris (2015) also claimed that OTPDPs that responded to teachers' expectations and needs were more likely to yield positive teaching and learning outcomes. Moreover, effective OTPDPs should incorporate different design elements, such as pedagogical content knowledge, flexibility, and easy learning activities (Bragg et al., 2021). In short, effective OTPDPs should be long-term, realistic (Huang, 2002), and field-specific programs that provide interactive learning platforms (ILPs) (Schachter et al., 2019), facilitate group work (Donohoo et al., 2018; Sancar et al., 2020), and focus on content knowledge and pedagogical skills (Garner & Kaplan, 20201). Moreover, effective OTPDPs should address technological and pedagogical content knowledge as a whole (Polly & Martin, 2020; Powell & Bodur, 2019). Therefore, a long-term OTPDP tailored to professional development in STEM education was designed in the present study.

Effective Professional Development in STEM Education

In the last decade, countries have put in a great deal of effort to designing and providing quality STEM education (Ring et al., 2017) because they are interested in attracting more students to STEM fields and preparing them for the business world of the twenty-first century (Yıldırım, 2020b). People with the skills necessary for the business world are more likely to adapt to professional transformations and find jobs. In a sense, this can reduce unemployment, which is quite common among young people (Akcan, 2019). To achieve that, people need to start with STEM education at a young age. However, half of the students lose interest in STEM fields before reaching eighth grade (Allen, 2016). Those who lose interest in STEM fields are less likely to consider pursuing careers in those fields (Brophy et al., 2008). Effective STEM education programs are required to make students more interested in STEM fields (National Research Council [NRC], 2011). Teachers are primarily responsible for applying STEM education programs and improving students' academic performance (Çorlu et al., 2014; Nguyen et al., 2020). For example, Hibpshman (2007) argued that teachers' science and math competence were correlated with students' academic performance. However, teachers have low performance because there are few STEM professional development programs (Ejiwale, 2013). Therefore, teachers need a well-planned and robust pedagogical education to develop STEM skills (The President's Council of Advisors on Science and Technology [PCAST], 2010). Both students and teachers can benefit from pedagogically-robust STEM education that focuses on twenty-first-century skills. Teachers who receive well-planned pedagogical STEM education are more likely to find jobs and work in better conditions.

Teachers should have a sound grasp of STEM education to use it in their lectures (Pang & Good, 2000) because content knowledge is of significance to integrate STEM education into teaching (Hackman et al., 2021). Teachers with little pedagogical content knowledge have difficulty integrating STEM into their lectures (Stinson et al., 2009) and have negative attitudes towards it (Jamil et al., 2018). Therefore, qualified teachers are needed for sustainable STEM education (Nguyen et al., 2020). STEM lesson planning also affects how well teachers apply STEM education (Yıldırım, 2020b). Lesson plans help teachers deliver STEM education calculatedly and effectively (Kablan, 2012). Therefore, Margot and Kettler (2019) argued that STEM education should be integrated with OTPDPs to improve teachers' STEM performance. STEM education integrated with OTPDPs also promotes social development (NRC, 2011; Reeve, 2015). Therefore, OTPDPs tailored to STEM education should be at least 80 hours of applied training (Johnson & Fargo, 2010; Supovitz & Turner, 2000) and facilitate the use of STEM knowledge, skills, and technology (Affouneh et al., 2020). STEM education, course contents, and PDPs should be designed according to the needs of the labor market for high academic benefits and employment rates. In fact, career counselors should also receive STEM education and help authorities develop robust STEM education, course contents, and PDPs. In this way, both teachers and students can benefit from STEM education.

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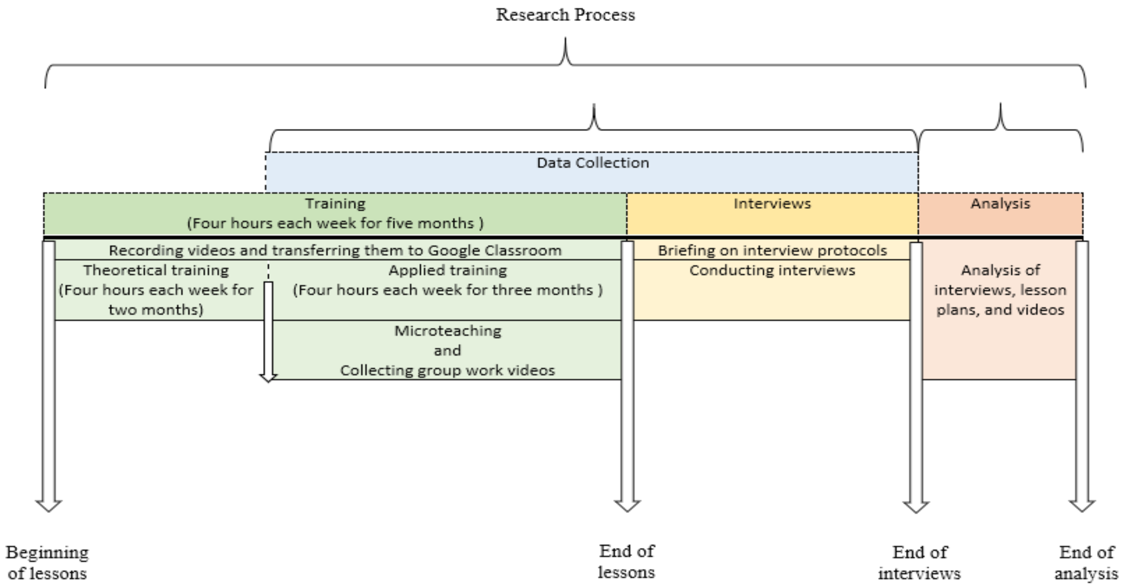
Research Methodology

Research Model and Procedure

An ontological and epistemological perspective is needed to address different aspects of a case (Twining et al., 2017). Therefore, how to construct the information about a given case and how to access and define it should be considered. In the present study, both experimental and interpretative paradigms were put to use to that end. In other words, this study adopted a postpositivist perspective to determine the effect of OTPDP tailored to STEM education on teacher professional development (Creswell & Poth, 2017). The study divided the main research problem into four research questions and employed a qualitative type of research (a single case study) to seek answers to the questions through data source diversification. Figure 1 shows the research process.

Figure 1
Research Process



Research Context and Sample

Criterion sampling was used to select participants (Patton, 2002). It is a non-probability purposive sampling method that allows the researcher to recruit people who satisfy certain criteria (Yıldırım & Şimşek, 2011). It is a time- and cost-effective and objective-focused method (Platton, 2002). One hundred and twenty-six teachers enrolled in OTPDPs for STEM education. The teachers who met the inclusion criteria were included in the sample.

The inclusion criteria were (1) having completed OTPDPs tailored to STEM education, (2) having taken part in ILPs, (3) planning lessons based on the program, and (4) volunteering. The study also took teachers' branches, experience levels, and educational backgrounds into account to obtain detailed information about the process. The sample consisted of 36 teachers who met the inclusion criteria. Table 1 shows the inclusion criteria and their frequencies.

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Table 1
Inclusion Criteria and Their Frequencies

Theme	Codes	Frequency
Criteria	Having completed OTPDPs tailored to STEM education	98
	Having taken part in ILPs,	89
	Planning lessons based on the program,	75
	Volunteering	36

Ninety-eight participants completed OTPDPs tailored to STEM education. Of those participants, 89 took part in ILPs. Of the 89 participants, 75 prepared lesson plans. Of the 75 participants, 36 agreed to be interviewed (Table 1). Table 2 shows the participants' demographic characteristics.

Table 2
Demographic Characteristics

Themes	Codes	*f*
Gender	Woman	26
	Man	10
	Total	36
Work Experience (years)	1-10	26
	11-20	8
	21 or more	2
	Total	36
Line of Service	Kindergarten	2
	Primary school	10
	Lower-secondary school	22
	Upper-secondary school	2
	Total	36

The OTPDP for STEM education was based on the online professional development standards laid down by the SREB (2004), ISTE (2008), and INACOL (2011). STEM education for online professional development was based on STEM pedagogical content knowledge (STEM PCK), STEM teacher institutes training model (STEM-TITM), and STEM teacher professional development program (STEM-TPDP). The OTPDP process consisted of five stages: accepting applications, design, training, evaluation, and data collection. The stages were explained in detail below:

1. **Accepting applications:** Participants were selected from applicants. Each participant was informed about the research purpose and procedure and the training protocol.
2. **Design:** This stage consisted of four steps: (1) determining needs, (2) creating content catering for those needs, (3) planning the training, and (4) choosing interactive learning tools for the training.
   - **Determining Needs*:*** A needs analysis was conducted.
   - **Creating Content**: Content was created based on the needs. It consisted of STEM PCK, STEM-TITM, and STEM-TPDP.
   - **Planning Training*:*** The OTPDP was conducted six hours a week for five months.
   - **Choosing Interactive Learning Tools*:*** The OTPDP was designed in a way to promote collaboration and interaction. The training involved different ILPs (Google Classroom, Padlet, Zoom, etc.) to encourage participants to do activities together and exchange information.

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3. **Training:** The OTPDP training consisted of five steps: (1) teaching STEM educational content, (2) reading sources, (3) microteaching, (4) lesson planning, and (5) presenting sample STEM activities and getting participants to design their own activities.
   - **Teaching the STEM educational content*:*** Participants were provided with the STEM educational content according to the STEM PCK and STEM-TITM.
   - **Reading sources*:*** Participants read and discussed the sources provided throughout the training.
   - ***Microteaching:*** Participants made presentations on the assignments they were given during the training. The presentations were videotaped.
   - **Lesson planning:** Participants planned lessons tailored to STEM education.
   - **Presenting sample STEM activities and getting participants to design their own activities*:*** Participants were provided sample STEM activities and then were asked to design their own activities.
4. **Evaluation:** Participants' performance during and after the training was evaluated.
5. **Data collection:** Data were collected through lecture videos and lesson plans (during training) and interviews (after training).

Instrument Used and Their Validation

Online Teacher Professional Development Form (OTPDF)

Participants were interviewed to find out what they thought about OTPDPs for STEM education. An interview form was developed by the researchers in six stages. First, the literature was reviewed (Ching & Hursh, 2014; Parsons et al., 2019; Powell & Bodur, 2019). Second, a pool of items was generated ($n = 10$). Third, two experts were consulted for intelligibility. Fourth, the form was modified according to expert feedback. Fifth, a pilot test was undertaken ($n=2$). Sixth, the form was finalized according to the pilot test results.

STEM Lesson Plans

Participants planned lessons as part of the OTPDP. Those plans were used to evaluate their STEM performance and to determine whether qualitative data corroborated.

Data Analysis

The researchers contacted each participant and informed him/her of the purpose and schedule of the face-to-face interview. Each interview lasted 20 to 27 minutes (732 in total) and was recorded. The interview data were analyzed using inductive content analysis. First, the researchers transcribed the interviews, and then two experts analyzed them. They developed themes, categories, and codes and calculated the interrater reliability, which was 86% (Miles & Huberman, 1994).

The lesson plans were analyzed using the evaluation criteria for STEM lesson plans based on the literature review (Kim et al., 2015; Wang et al., 2011; Yıldırım, 2020b). They were all shared criteria. For example, the criteria of "robotic" laid down by Kim et al. (2015) was removed. The criteria of "duration" and "time-appropriateness" used by Wang et al. (2011) and Yıldırım (2020b) were removed because the lesson plans indicated how many hours of class they would last. All criteria but these were removed. Afterward, the lesson plans were analyzed by two experts. The interrater reliability was 86%. Table 3 shows the evaluation criteria for STEM lesson plans.

Table 3
Evaluation Criteria for STEM Lesson Plans and Their Definitions

No	Criteria	Definition
1	Setting goals (SG)	Specifying the target goals; incomplete in case of one or two missing
	Choosing topics (CT)	Specifying all topics of interest; incomplete in case of one or two missing

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No	Criteria	Definition
3	STEM Inclusion (SI)	The focus of science (FS) The focus of mathematics (FM) The focus of engineering (FE) The focus of technology (FT) The focus of social science (FSS)
4	Ensuring STEM integration (ESI)	Specifying all STEM fields (science, math, engineering, and technology)
5	Ensuring İnterdisciplinarity (EID)	Integrating at least two disciplines
6	specifying strategies, methods, and techniques (STMT)	Specifying in the lesson plan all strategies, methods, and techniques
7	Grade level-appropriateness (GLA)	Grade level-appropriate lesson plans
8	relating to everyday life (REDL)	Relating topics to everyday life
9	Applicability (APP)	Applicability of the lesson plan
10	Specifying assessment tools (SAT)	Specifying the ways of evaluating the lesson plan

Reliability and validity were evaluated using different methods. The codes and themes were developed by two experts to reduce researcher bias in the qualitative data and to ensure internal validity. The inter-coder reliability was calculated using the formula proposed by Miles and Huberman (1994). Direct quotations were used to present the situation as it was. The lesson plans and videos were also evaluated and coded by the two experts. Miles and Huberman's (1994) formula was used to calculate the inter-coder reliability. The data source diversification method was also used to improve the reliability of the findings. It helped us conduct a comparative analysis and provide a holistic picture of the process (Lincoln & Guba, 1985).

Research Results

Participants' Perceptions of OTPDPs

The results of the first research question were presented in tables. Direct quotations were used to allow readers to interpret the findings.

Reasons for Attending the OTPDP

First, the first research question focused on why participants attended the OTPDP. Table 4 presents the reasons participants attended the OTPDP.

Table 4
Reasons for Attending the OTPDP

Themes	Categories	Codes	Quotes
Reasons for Attending the OTPDP	Of teacher origin	Professional development (*n* = 13)	*To see the gaps in my knowledge.*
		Making use of it in class (*n* = 2)	*To put them into practice in my lessons so that students can come up with ideas and realize them*
	Of student origin	Student development (*n* = 5)	*I needed STEM education to help my students develop 21st-century skills.*
	Of content origin	Content (*n* = 10)	*I attended the training because it was about STEM education.*

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Themes	Categories	Codes	Quotes
	Of environment and condition origin	Flexibility (*n* = 16)	*I can take the classes whenever I want, especially the evening classes.*
		Lecture videos (*n* = 9)	*I attended it because I could watch the recordings of the classes that I missed.*
		Inexpensive (*n* = 9)	*Online teacher professional development programs are cheap.*
		Accessible (*n* = 7)	*I attended it because I could take it anywhere and anytime.*
		Beyond the limits of space (*n* = 10)	*I prefer to attend online education because I can take it wherever I am.*

Participants expressed different reasons for attending the OTPDP. They stated that they attended it because it was flexible and inexpensive, promoted professional development, and had appealing content (Table 4).

Participants' Perceptions of the OTPD

Second, the first research question addressed participants' perceptions of the OTPDP. Table 5 presents participants' perceptions of the OTPDP

Table 5
Participants' Perceptions of the OTPDP

Themes	Categories	Codes	Quotes
Participants' Perceptions of the OTPDP	Professional knowledge	Learning STEM education (*n* = 17)	*It was the most accurate STEM education source; I brushed up on things I probably forgot, and I learned new things.*
		Professional development (*n* = 13)	*I've become more professionally competent, and I've had a lovely time during the pandemic.*
		Pedagogical knowledge (*n* = 11)	*It was an online program, but I've learned about pedagogy.*
		Concept teaching (*n* = 11)	*I've learned a lot of concepts, and I've improved myself, engineering-wise.*
		Dispelling misconceptions (*n* = 1)	*I've found out that some things I thought were right were actually wrong, and I got a chance to fix them.*
	Professional skills	Sharing knowledge (*n* = 2)	*It was very useful to share knowledge with people from different cities and different branches.*
		Sharing experience (*n* = 2)	*It allows colleagues to share their experiences.*
		Feedback-correction (*n* = 6)	*It is nice to get instant feedback online.*
	Features	Quality content (*n* = 10)	*It's a professional training program, and so I feel professionally more competent.*
		Beyond the limits of space (*n* = 8)	*No space limit in online education*
		Flexibility (*n* = 8)	*We got to attend classes without worrying about time constraints.*
		Group work (*n* = 7)	*It gave us the opportunity to work with other people.*
		Serving the needs (*n* = 3)	*It's designed to meet the needs of teachers.*
		Interactive learning environment (*n* = 3)	*It integrates different platforms, such as forum and Zoom.*
		Microteaching (*n* = 2)	*It was nice to be involved. Presentation is the best way to learn things.*

Participants' perceptions of OTPDPs were grouped under the dimensions of professional knowledge, professional skills, and characteristics (Table 4). The OTPDP helped participants acquire professional knowledge and develop professional skills. The program appealed to them because they enjoyed the quality content and attended the classes whenever and wherever they wanted (Table 5).

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Challenges of the OTPDP and Solutions

Third, the first research question concentrated on the challenges of the OTPDP and participants' solutions to them. Tables 6 and 7 presents the challenges of the OTPDP and participants' solutions to them.

Table 6.
Challenges of the OTPDP

Themes	Categories	Codes	Quotes
Challenges of the OTPDP	Of environment and condition origin	Internet connection issues (*n* = 14)	*I had some Internet connection issues, but that was all.*
		Health issues (*n* = 3)	*The training is too long; my eyes and back hurt after a certain point.*
		Unsuitable home environment (*n* = 2)	*I sometimes missed classes because of family matters.*
		Computer-related problems (*n* = 2)	*My computer was overheating.*
		Lessons taking too long (*n* = 2)	*The lessons were sometimes too long.*
		Limited Internet quota (*n* = 2)	*The live classes dried up my Internet quota.*
		Power shortages (*n* = 2)	*We sometimes had power shortages.*
	Of teacher origin	Inability to attend live classes (*n* = 6)	*Some days, the lectures and exams overlapped. They were at the same time and on the same day, so I missed some classes.*
		Inability to adapt to technology (*n* = 3)	*I'm not tech-savvy, and it made me nervous.*
		Communication problems (*n* = 2)	*It was online, and so, we sometimes had communication problems.*

Participants faced different challenges during the OTPDP. Most of them referred to the problems of environment/condition origin and personal problems (Table 6).

Table 7
Solutions to OTPDP Problems

Themes	Categories	Codes	Quotes
Solutions	Related to content	Recording lectures (*n* = 20)	*I had no problems other than my son's bedtime. I missed only one minute or two, but all classes were recorded, so it was no longer a problem.*
		More reading activities (*n* = 4)	*We should read a lot of books to fill in the gaps in our knowledge.*
	Related to environment/condition	Alternative tools (*n* = 2)	*I used my phone when my computer crashed.*
		Shorter classes (*n* = 12)	*Classes should be shorter.*
	Related to training	Blended learning (*n* = 2)	*Blended learning at least allowed us to come face to face and address and convey the affective dimension.*

Participants proposed different solutions to the challenges presented by the OTPDP and made suggestions regarding the content, training, and environment/condition (Table 7).

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Group Work during the OTPDP

Fourth, the first research question looked into participants' perceptions of group work during the OTPDP. Table 8 presents the participants' perceptions of group work during the OTPDP.

Table 8
Participants' Perceptions of Group Work During the OTPDP

Themes	Categories	Codes	Quotes
Group Work	Necessary conditions for cooperative learning	Shared goals (*n* = 5)	*It is valuable because participants collaborate for a common goal.*
		Bonding (*n* = 4)	*It definitely improves the sense of group belonging.*
		Taking responsibility (*n* = 3)	*It encouraged us to take responsibility.*
		Social skills (*n* = 3)	*We got to meet colleagues.*
	Technology literacy	Increase in technology knowledge (*n* = 10)	*I feel like I acquired technological and pedagogical content knowledge.*
		Technological developments	*Keeping up with technological developments and putting lesson plans to use*
	Lesson plan	Recognizing the shortcomings of the lesson plan (*n* = 7)	*I wish we always had this training because it got me to see the problems with my lesson planning.*
		Facilitating the lesson planning process (*n* = 3)	*We completed the tasks more easily and faster.*
	Communica-tion and collaboration	Sharing experience (*n* = 10)	*Exchanging ideas with colleagues and becoming aware of their experiences*
		Exchanging ideas (*n* = 7)	*We made up for our weaknesses by sharing what we learned with each other.*
	Content knowl-edge	Science knowledge (*n* = 4)	*It provided very good interaction, and I got to learn a lot about things I knew little (science, physics, etc.).*
		Engineering knowledge (*n* = 2)	*Acquiring new knowledge of engineering*
	21st-century skills	Critical thinking (*n* = 8)	*It let me and my colleagues from different branches rethink things from a critical perspective.*
		Creative thinking (*n* = 3)	*Different perspectives positively affect our creativity.*
		Problem-solving (*n* = 2)	*We get to solve problems with lesson plans.*

Participants differed on the positive aspects of group work and noted that it provided the necessary conditions for cooperation, improved technological literacy, contributed to the lesson planning process, and helped them acquire content knowledge and develop 21st-century skills (communication, collaboration, etc.) (Table 8).

Interactive Learning Platforms in the OTPDP

Fifth, the first research question addressed participants' perceptions of interactive learning platforms in the OTPDP. Table 9 presents the participants' perceptions of interactive learning platforms in the OTPDP.

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Table 9
Participants' Perceptions of Interactive Learning Platforms in the OTPDP

Themes	Categories	Codes	Quotes
Interactive Learning Platforms	Professional knowledge	Technology literacy (n = 23)	*Though effective and efficient use of technology is imperative, the program has made an incredible contribution to technology literacy.*
		Professional development (n = 6)	*It's contributed to the learning and use of different applications and our professional development.*
	Professional skill	Effective communication (n = 20)	*It is both an alternative and a facilitator of communication and interaction.*
		Cooperation (n = 13)	*It enables teachers to work together.*
		Increasing interaction (n = 12)	*I find it efficient because we get to interact with tools.*
		Feedback-correction (n = 6)	*It is very important and advantageous for instant feedback.*
		Sharing knowledge (n = 4)	*It helps us share knowledge.*
		Sharing experience (n = 2)	*Taking advantage of each other's experience improves our professional development.*

Participants addressed many positive contributions of ILPs. They noted that ILPs improved their technological literacy and communication competence and encouraged them to cooperate to accomplish tasks (Table 9).

Microteaching in the OTPDP

Sixth, the first research question looked into participants' perceptions of microteaching. Table 10 presents the participants' perceptions of microteaching.

Table 10
Participants' Perceptions of Microteaching

Themes	Categories	Codes	Quotes
Microteaching	Professional development	Recognizing shortcomings (n = 12)	*The presentations helped us see our shortcomings.*
		Developing communication skills (n = 6)	*We have made up for our shortcomings in things like effective speaking and achieved new outcomes.*
		Time management (n = 6)	*I tried hard to use the time effectively during the presentations.*
		Self-confidence (n = 2)	*The presentations made me more self-confident.*
	Scientific process skills	Observation (n = 8)	*I had the opportunity to observe myself and others.*
		Drawing conclusions (n = 4)	*I observed my friends before deciding what to do.*
	Learning approach	Learning by doing and living (n = 7)	*It made learning by doing and living possible.*
		Hands-on learning (n = 7)	*The best way to learn something is to practice it. The more you do it, and the more you share it, the more you realize how much you've learned it.*
	Evaluation	Self-assessment (n = 8)	*It allows us to evaluate ourselves more objectively.*
		Peer assessment (n = 4)	*My colleagues evaluated my lesson plan, and I evaluated theirs, which made me more experienced when it comes to STEM lesson planning.*
	Negative aspects	Stress and anxiety (n = 6)	*The presentations made me nervous and stressed out.*
		Getting too nervous (n = 4)	*I tried to keep my shakes under control during the presentation.*

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Participants approached microteaching during the OTPDP from different perspectives and remarked that it helped them see their shortcomings, develop communication skills, and learn by doing and living. Some participants pointed out that the presentations made them nervous or distressed (Table 10).

Participants' Perceptions of the Reflection of the OTPDP on STEM Lesson Planning

Each question of the second research question was presented in tables. Each table included quotations to help readers interpret the findings.

The Reflection of the OTPDP on STEM Lesson Planning

First, the second research question addressed participants' perceptions of the reflection of the OTPDP on STEM lesson planning. Table 11 shows the participants' perceptions of the reflection of the OTPDP on STEM lesson planning.

Table 11
The Reflection of the OTPDP on STEM Lesson Planning

Themes	Categories	Codes	Quotes
Reflection of OTPDP on STEM Lesson Planning	Lesson plan content	Lesson planning (*n* = 19)	*I didn't know how to plan lessons, but the program taught me how to do it.*
		Drawing up quality lesson plans (*n* = 13)	*I saw my lesson plan's weaknesses and strengths, and I did a better job the next time.*
		Detecting shortcomings (*n* = 10)	*The examples and criticisms made me see the mistakes in my lesson plan.*
		Recognizing strengths (*n* = 4)	*Now I know what the strengths of my lesson plan are.*
	Communication and collaboration	Developing a different perspective (*n* = 5)	*I've developed different perspectives about lesson planning.*
		Exchanging ideas (*n* = 4)	*The exchange of ideas helped us see the mistakes in our lesson plans and put them right.*
	Diversity	Checking on other lesson plans (*n* = 4)	*Thanks to online learning, we got to see different lesson plans.*
		Using different technological tools (*n* = 8)	*We got to use different technological tools.*
		Using different methods/techniques (*n* = 3)	*I've learned about different methods and techniques.*

Participants thought that the OTPDP had positive reflections on lesson planning. They highlighted that the OTPDP helped them draw up better and higher-quality lesson plans and see their own shortcomings (Table 11). The results showed that the OTPDP had positive reflections on participants' lesson planning. Participants addressed that the OTPDP helped them draw up better and higher-quality lesson plans and see their own shortcomings (Table 11).

The Challenges of STEM Lesson Planning and Solutions

Second, the second research question looked into the challenges of STEM lesson planning and participants' solutions to them. Tables 12 and 13 present the challenges of STEM lesson planning and participants' solutions to them.

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Table 12
Challenges of STEM Lesson Planning

Themes	Categories	Codes	Quotes
Challenges	Lack of content knowledge	Inability to integrate STEM (n = 15)	*It made me realize that it was hard to integrate STEM into lesson plans.*
		Engineering knowledge (n = 12)	*The greatest challenge for me was to integrate engineering into the lesson plan. It made me realize that I didn't know some things I should have.*
		Technological knowledge (n = 10)	*I realized that I didn't know much about technology.*
		Math knowledge (n = 7)	*I should focus on math because I had a hard time integrating it into my lesson plan because I just didn't know how.*
		Science knowledge (n = 4)	*I had a hard time because I had some gaps in my knowledge of science.*
	Lack of resources	Lack of sample lesson plans (n = 5)	*One of the difficulties is that there are no field-specific sample lesson plans.*
		Lack of books (n = 2)	*There are not enough books we can read about this.*
	Student	Level-appropriateness (n = 1)	*I realized that I overlooked students' levels when planning the lesson.*
	Time management	Time management (n = 1)	*I had a hard time managing time.*

Participants stated that they experienced different problems during STEM lesson planning. They had a hard time planning lessons due to the lack of resources and knowledge. They also noted that they had difficulty managing time and catering for student-level when planning lessons (Table 12).

Table 13
Solutions to Challenges of STEM Lesson Planning

Themes	Categories	Codes	Quotes
Solutions	Collaboration	Group work (n = 19)	*I think that group work is the best solution.*
		Working with branch teachers (n = 17)	*I think teachers from different branches should plan lessons altogether.*
		Getting expert support (n = 5)	*We can ask experts for help.*
	Resources	Checking sample lesson plans (n = 6)	*I guess the best solution is to go through lots of sample lesson plans.*
		Checking the curriculum (n = 3)	*Checking the curriculum can help solve integration problems.*
		Reading books (n = 2)	*We have to read books about it.*

Participants proposed different solutions to the problems they faced during STEM lesson planning and stated that they could plan lessons better if they worked with teachers from different branches and received expert support. They also remarked that they should work on sample lesson plans, check the curriculum, and read books to improve their lesson planning skills (Table 13).

What to Consider When Planning STEM Lessons

Third, the second research question looked into participants' perceptions of what to consider when planning STEM lessons. Table 14 presents the participants' perceptions.

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Table 14
What to Consider When Planning STEM Lessons

Themes	Categories	Codes	Quotes
Thing Taken into Account When Planning STEM Lessons	Content knowledge	Integration of engineering (*n* = 11)	I made sure that I used engineering design processes.
		Integration of technology (*n* = 9)	I did some research on how to use technology.
		Integration of math (*n* = 7)	I chose activities to answer the question, "When am I ever going to use math in real life?"
		21st-century skills (*n* = 6)	I focused on 21st-century skills.
	Planning education	Goal-directed (*n* = 13)	I first focused on learning outcomes.
		Applicability (*n* = 9)	I made sure that the lesson plan was applicable.
		Student-level (*n* = 7)	I made sure that I tailored the lesson plan to my students' levels.
	Managing the teaching-learning process	Method and technique (*n* = 5)	I integrated engaging methods and techniques into the lesson plan.
		Suitable for the environment (*n* = 6)	Their immediate environment, class position, and culture are important.
		Relatability (*n* = 9)	I made sure that the outcomes were related to everyday life.

Participants paid attention to different things while planning lessons. They focused on integrating engineering and technology into their lesson plans. They also made sure that the lesson plans were goal-directed, applicable, and relatable (Table 14).

The Effect of the OTPDP on STEM Teaching

Participants' lesson plans were analyzed according to predetermined criteria to evaluate the effect of the OTPDP on STEM teaching. The first and revised versions of the lesson plans were compared. In this way, raw data were used to help readers interpret the findings.

Analysis of the First Lesson Plans

Most participants had a hard time integrating technology into their first lesson plans, while others could not integrate math, engineering, natural sciences, and social sciences. Those who managed to integrate science, math, and technology focused on similar areas, such as "physics" in science class, "ratio and proportion" in math class, and "video and computer" in technology class. Some participants did not specify the goals and subjects in their lesson plans. Participants had no problems with EID, STMT, GLA, REDL, APP, and SAT. Although they had no problems with SAT, they used a similar assessment tool in their lesson plans. This showed that they had a gap in their STEM pedagogical content knowledge. Figures 2, 3, and 4 show the analysis of the first lesson plans.

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Figure 2

Review of The First STEM Lesson Plans (Participants from 1 to 12)

No	Teacher	Criteria													
		SG	CT	SI					ESI	EID	STMT	GLA	REDL	APP	SAT
				FS	FM	FT	FE	FSS							
1	Esra	Yes	Yes	Light	Angle	Video, Computer	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Self-assessment
2	Adem	Missing	Missing	None	Geometry	Video	None	None	None	None	Yes	Yes	No	Yes	Interview
3	Tayfun	Yes	Yes	Light, Noise	Length	Video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
4	Veli	Yes	Yes	The reflection of light	Agle	Video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
5	Selin	Missing	Missing	None	Measurement	Video, Computer	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric, Peer assessment
6	Ceylan	Yes	Yes	Light, Noise	Data processing, Measurement	Scratch, Computer	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubrik, Question
7	Naz	Missing	Missing	Liquid Pressure	none	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric
8	Ebru	Yes	Yes	Waves	Possibility, Data processing,	Scratch, computer	Engineering design cycle	Music	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
9	Medine	Yes	Yes	Frictional Force	none	Video, drone	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	None
10	Feray	Mising	Miising	None	Possibility	none	none	None	None	None	Yes	Yes	Yes	Yes	Multiple Choice Exam
11	Osman	Yes	Yes	Pressure	Triangles Geometric solid	Video, computer	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
12	Halil	Yes	Yes	Matter, Heat	None	Video, computer	Engineering design cycle	Social studies	None	Yes	Yes	Yes	Yes	Yes	Rubric

Figure 3

Review of the First STEM Lesson Plans (Participants from 13 to 24)

No	Teacher	Criteria													
		SG	CT	SI					ESI	EID	STMT	GLA	REDL	APP	SAT
				FS	FM	FT	FE	FSS							
13	Serkan	Yes	Yes	Energy transformatio n	Ratio and proportion	None	Engineering design cycle	History	None	Yes	Yes	Yes	Yes	Yes	Rubric, open ended questions
14	Canan	Missing	Missing	Electric Circuits	Problem solving	Scratch	None	None	None	Yes	Yes	Yes	Yes	Yes	None
15	Duygu	Yes	Yes	Energy transformatio n	Monies	Web 2.0 tools Video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric Interview
16	Semra	Yes	Yes	Flora	None	None	Engineering design cycle	None	No	Yes	Yes	Yes	Yes	Yes	Rubric
17	Hamza	Yes	Yes	Air resistance	Length, Angle	Video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
18	Sinem	Yes	Yes	Light	Angle	Computer	Engineering design cycle	Social studies	Yes	Yes	Yes	Yes	Yes	Yes	None
19	Feyza	Yes	Yes	Light, Lens	Field measurement, Circle	360 VR	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
20	Gül	Missing	Missing	Light	Reflection, Line segment	Computer, video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
21	Mustafa	Missing	Missing	water cycle drought	Graphical display	Computer, video	Engineering design cycle	History	Yes	Yes	Yes	Yes	Yes	Yes	Rubric, open ended questions
22	Ayça	Yes	Yes	Organism, non-living thing	Notation	Video	None	None	None	None	Yes	None	None	None	Question
23	Tansu	Missing	Missing	recycling	Geometric solid	Web 2.0 tools	None	None	None	None	Yes	Yes	None	Yes	Rubric
24	Ayla	Missing	Missing	Pressure	Ratio and proportion	Computer, Thincarked	None	None	None	None	Yes	Yes	None	Yes	Rubric

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Figure 4
Review of the First STEM Lesson Plans (Participants from 25 to 36)

No	Teacher	Criteria													
		SG	CT	SI					ESI	EID	STMT	GLA	REDL	APP	SAT
				FS	FM	FT	FE	FSS							
25	Ahmet	Yes	Yes	Electric Circuits	Data collection	Video, bilgisayar	Engineering design cycle	Turkish lesson	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
26	Gülsüm	Yes	Yes	Organism	Notation Geometric solid	None	None	None	None	None	Yes	Yes	None	Yes	None
27	Handan	Yes	Yes	Magnet	Mensuration	Video Web 2.0 tools	Engineering design cycle	Social studies	Yes	Yes	Yes	Yes	None	Yes	None
28	Hale	Yes	Yes	Pressure	Ratio and proportion	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric, Portfolio
29	Dilek	Yes	Yes	Density	Ratio and proportion	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Self-assessment
30	Demet	Yes	Yes	None	None	Video	Engineering design cycle	None	None	None	Yes	Yes	Yes	Yes	Rubric
31	Ali	Yes	Yes	None	Fractions	Smart board Piano, Computer	Engineering design cycle	Music	None	Yes	Yes	Yes	Yes	Yes	Rubric
32	Derya	Yes	Yes	None	None	Computer, video	Engineering design cycle	Turkish lesson	None	Yes	Yes	Yes	Yes	Yes	Rubric
33	Deniz	Missing	Missing	Energy transformation	Ratio and proportion	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric
34	Filiz	Missing	Yes	Minnors	None	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric
35	Bilge	Yes	Yes	neural system	Ratio and proportion	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric
36	Fatma	Missing	Missing	Heat, heat insulation	Percentage	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric

Analysis of the Revised Lesson Plans

Participants had a hard time integrating STEM fields into their revised lesson plans. Just like in the first lesson plans, they focused on "physics" in science class, "ratio and proportion" in math class, and "video and computer" in technology class and used rubric as the assessment tool. However, they integrated more technological and assessment tools into their revised lesson plans, pointing to improved technological literacy. There was no difference in the level of social science integration between the first and revised lesson plans. Participants had no difficulty setting goals and choosing subjects and had no problems with EID, STMT, GLA, REDL, APP, and SAT. This shows that they learned new things about STEM pedagogical content. Figures 5, 6, and 7 show the analysis of the first lesson plans.

Figure 5
Review of the Revised STEM Lesson Plans (1 to 12)

No	Teacher	Criteria													
		SG	CT	SI					ESI	EID	STMT	GLA	REDL	APP	SAT
				FS	FM	FT	FE	FSS							
1	Esra	Yes	Yes	Light	Angle	Video, Computer	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Self-assessment
2	Adem	Yes*	Yes*	Mirrors*	Geometry	Video	Engineering design cycle*	None	Yes*	Yes*	Yes	Yes	Yes*	Yes	Interview
3	Tayfun	Yes	Yes	Light, Noise	Length	Video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
4	Veli	Yes	Yes	The reflection of light	Angle	Video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
5	Selin	Yes*	Yes*	None	Measurement	Video, Computer	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric, Peer assessment
6	Ceylan	Yes	Yes	Light, Noise	Data processing, Measurement	Scratch, Computer	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubrik, Question
7	Naz	Yes*	Yes*	Liquid Pressure	Whole numbers*	Video*	Engineering design cycle	None	Yes*	Yes	Yes	Yes	Yes	Yes	Rubric
8	Ebru	Yes	Yes	Waves	Possibility, Data processing,	Scratch, Computer	Engineering design cycle	Music	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
9	Medine	Yes	Yes	Frictional Force	Geometric solid *	Video, drone	Engineering design cycle	None	Yes*	Yes	Yes	Yes	Yes	Yes	Rubric*
10	Feray	Yes*	Yes*	None	Possibility	Scratch, Computer*	none	None	None	Yes*	Yes	Yes	Yes	Yes	Multiple Choice Exam
11	Osman	Yes	Yes	Pressure	Triangles Geometric solid	Video, Computer	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
12	Halil	Yes	Yes	Matter, Heat	Profit and loss *	Video, Computer	Engineering design cycle	Social studies	Yes*	Yes	Yes	Yes	Yes	Yes	Rubric

*Corrections and additions

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Figure 6

Review of the Revised STEM Lesson Plans (13 to 24)

No	Teacher	Criteria													
		SG	CT	SI					ESI	EID	STMT	GLA	REDL	APP	SAT
				FS	FM	FT	FE	FSS							
13	Serkan	Yes	Yes	Energy transformation	Ratio and proportion	Computer*	Engineering design cycle	History	Yes*	Yes	Yes	Yes	Yes	Yes	Rubric, open ended questions
14	Canan	Yes*	Yes*	Electric Circuits	Problem solving	Scratch, Computer	Engineering design cycle*	None	Yes*	Yes	Yes	Yes	Yes	Yes	Rubric*
15	Duygu	Yes	Yes	Energy transformation	Monies	Web 2.0 tools, video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric Interview
16	Semra	Yes	Yes	Flora	Monies*	Computer*	Engineering design cycle	None	Yes*	Yes	Yes	Yes	Yes	Yes	Rubric
17	Hamza	Yes	Yes	Air resistance	Length, Angle	Video, Computer Web 2.0 tools*	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric, open ended questions*
18	Sinem	Yes	Yes	Light	Angle	Video, Computer	Engineering design cycle	Social studies	Yes	Yes	Yes	Yes	Yes	Yes	Rubric, open ended questions*
19	Feyza	Yes	Yes	Light, Lens	Field measurement, Circle	360 VR	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
20	Gül	Yes	Yes	Light	Reflection, Line segment	Computer, video	Engineering design cycle	None	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
21	Mustafa	Yes*	Yes *	water cycle drought	Grafik ile gösterme	Computer, video	Engineering design cycle	History	Yes	Yes	Yes	Yes	Yes	Yes	Rubric, open ended questions
22	Ayça	Yes	Yes	Organism, non-living thing	Notation	Scratch, Computer*	None	None	None	None	Yes	None	None	None	Question
23	Tansu	Yes*	Yes*	recycling	Geometric solid	Web 2.0 tools	Engineering design cycle*	None	Yes *	Yes*	Yes *	Yes*	Yes*	Yes	Rubric
24	Ayla	Yes*	Yes*	Pressure	Ratio and proportion	Computer Thincarked	Engineering design cycle*	None	No	No	Yes	Yes	No	Yes	Rubric

*Corrections and additions

Figure 7

Review of the Revised STEM Lesson Plans (25 to 36)

No	Teacher	Criteria													
		SG	CT	SI					ESI	EID	STMT	GLA	REDL	APP	SAT
				FS	FM	FT	FE	FSS							
25	Ahmet	Yes	Yes	Electric Circuits	Data collection	Video, computer	Engineering design cycle	Turkish lesson	Yes	Yes	Yes	Yes	Yes	Yes	Rubric
26	Gülsüm	Yes	Yes	Organism	Notation Geometric solid	Computer, video*	Engineering design cycle*	None	Yes *	Yes*	Yes	Yes *	Yes	Yes	Rubric, open ended questions
27	Handan	Yes	Yes	Magnet	Mensuration	Video, Web 2.0 tools	Engineering design cycle	Social studies	Yes	Yes	Yes	Yes	Yes*	Yes	Rubric *
28	Hale	Yes	Yes	Pressure	Ratio and proportion	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric, Portfolio
29	Dilek	Yes	Yes	Density	Ratio and proportion	Computer, video*	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Self-assessment
30	Demet	Yes	Yes	None	None	Video	Engineering design cycle	None	None	Yes *	Yes	Yes	Yes	Yes	Rubric
31	Ali	Yes	Yes	Sound *	Fractions	Smart board Piano, Computer	Engineering design cycle	Music	Yes *	Yes	Yes	Yes	Yes	Yes	Rubric
32	Derya	Yes	Yes	Flora*	Linear units *	Computer, video	Engineering design cycle	Turkish lesson	Yes *	Yes	Yes	Yes	Yes	Yes	Rubric
33	Deniz	Yes*	Yes*	Energy transformation	Ratio and proportion	Computer, Web 2.0 tools*	Engineering design cycle	None	Yes*	Yes	Yes	Yes	Yes	Yes	Rubric *
34	Filiz	Yes *	Yes	Minnors	Reflection, Geometry*	Web 2.0 tools, Computer*	Engineering design cycle	None	Yes *	Yes	Yes	Yes	Yes	Yes	Rubric
35	Bilge	Yes	Yes	neural system	Ratio and proportion	None	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric
36	Fatma	Yes *	Yes*	Heat, heat insulation	Percentage	Web 2.0 tools, video	Engineering design cycle	None	None	Yes	Yes	Yes	Yes	Yes	Rubric

*Corrections and additions

The reflection of the OTPDP in STEM Education regarding Teacher Employment

The fourth research question focused on participants' perceptions of the impact of OTPDPs in STEM education on teacher employment. All participants stated that OTPDPs in STEM education positively affected teacher employment. The following are direct quotes from participants:

> *P: We need STEM education to find jobs in the private or public sector, to make improvements according to needs, and to provide equal opportunities for everybody within the line of the welfare state system.*
>
> *P: This is an education model that we can use to deal with unemployment.*
>
> *P: Unemployment will be eliminated because STEM education helps teachers develop skills.*

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Participants were asked to explain the positive reflection of the OTPDP on STEM education regarding teacher employment. Table 15 presents the participants' perceptions.

Table 15
Participants' Perceptions of the Reflection of the OTPDP in STEM Education regarding Teacher Employment

Theme	Category	Codes	Quotes
the reflection of the OTPDP in STEM Education regarding Teacher Employment	Contribution to content knowledge	Technological content knowledge	The most important knowledge that a teacher who wants to find a job should have is technological knowledge. STEM education helps teachers acquire that knowledge.
		Engineering knowledge	Teachers must have engineering knowledge to help students develop products. STEM education can do that.
	Contribution to pedagogical knowl-edge and skills	Teaching-learning process	Teachers should be able to convey information to their students correctly. This is necessary to apply STEM education in the classroom.
		Planning education	It helped us plan lessons according to STEM education.
		21st century skills	STEM education helps teachers develop 21st-century skills, which is necessary for teachers.
		Interdisciplinarity	Today, interdisciplinary teachers can find jobs. This is achieved through STEM education.
		Technological literacy	Today, technology-literate people can easily find jobs. STEM education helps people develop technological literacy.

Participants stated different perceptions of the contribution of STEM education to teacher employment. They noted that STEM education helped teachers acquire content knowledge and develop pedagogical knowledge and skills. They emphasized that professional knowledge and skills were critical for employment.

Discussion

The first research question looked into the reasons for participants' attending the OTPDP. They attended the OTPDP because they liked its content and were interested in developing professional skills, integrating STEM education into their lectures, and ensuring student development. They also regarded the OTPDP as a flexible, inexpensive, and easy-to-access program with lecture videos that they could attend anywhere and anytime. Heap et al., (2020) also state that OTPDPs should be flexible, accessible, and affordable. The results are consistent with the literature (Martin, 2012; Persons et al., 2019; Robinson, 2008). For example, Powell and Bodor (2019) suggested that OTPDPs were flexible programs that helped teachers develop professional skills anywhere and anytime. Brooks and Gibson (2012) maintained that OTPDPs were appealing as they were flexible programs that facilitated communication and allowed teachers to attend classes anywhere and anytime.

The second part of the first research question addressed teachers' perceptions of the OTPDP. They stated that the OTPDP provided pedagogical knowledge, dispelled misconceptions, and taught them how to deliver STEM and conceptual education (professional knowledge). The OTPDP also helped them receive instant feedback, correct their errors, and share knowledge and experience (professional skills). Participants regarded the OTPDP as a flexible and interactive program that provided high-quality training and promoted group work and microteaching. Well-designed OTPDPs are supposed to encourage attendees to interact, share knowledge and experience, and improve themselves professionally (Eun, 2008; SREB, 2004). Alzahrani and Althaqafi (2020) also stated that OTPDPs helped teachers acquire professional knowledge and develop professional skills. Our results are consistent with the literature (Dede, 2006; INACOL, 2011; ISTE, 2008; Scott & Scott, 2010).

The third part of the first research question focused on what challenges teachers faced during the OTPDP and their solutions. Participants tackled Internet, health, and hardware/software problems, as well as power shortages (of environment and condition origin). They had a hard time attending some of the live classes, adapting to technology, and communicating (of teacher origin). They came up with solutions to problems regarding training, content, environment, and conditions. Although Internet access and infrastructure are critical for effective OTPDPs (Heap et al., 2020; Polly & Martin, 2020), online learning is imbued with connection or technical issues (Hodges et al., 2016; Sukhbaatar et al., 2018; Yıldırım, 2020a; Zhao, 2003).

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The fourth part of the first research question looked into what teachers thought about group work within the scope of the OTPDP. Participants stated that the OTPDP group work allowed them to set goals, take responsibility, develop social skills, and build a sense of group belonging (necessary conditions for cooperative learning). They noted that it helped them keep up with advances in technology and thus acquire technological knowledge (technological literacy). It also helped them see their shortcomings and plan lessons more easily (lesson plan). They acquired science and engineering knowledge (content knowledge) and developed 21st-century skills (problem-solving, creativity, and critical thinking). Palloff and Pratt (2005) argued that uniting for a common cause and bonding were critical for group work. Sancar et al. (2021) also stated that online discussion groups were critical for teacher professional development. Well-designed OTPDPs facilitate communication and collaboration (Ross, 2011; SREB, 2014). Research has shown that group work positively affects the OTPDP process (Conrad & Donaldson, 2004; Lederman & Niess, 1997; Vrasidas & Zembylas, 2014; Wang et al., 2011), which is consistent with our result.

The fifth part of the first research question discussed teachers' perceptions of the ILPs integrated into the OTPDP. Participants emphasized that the ILPs promoted communication, professional development, technological literacy, experience and knowledge sharing, and feedback-correction. Research has shown that well-designed OTPDPs with ILPs facilitate communication, collaboration, experience, and knowledge sharing (Bragg et al., 2021; Jamil & Hamre, 2018; SREB, 2014; Powell & Bodur, 2019). Liu (2012) saw ILPs as part of professional development. Lee et al. (2020) also stated that discussion forums promoted interaction and learning. Reeves and Pedulla (2013) highlighted that ILPs integrated into OTPDPs could contribute to professional development.

The sixth part of the first research question concentrated on participants' perceptions of microteaching within the scope of the OTPDP. Participants noted that microteaching allowed them to adopt new teaching approaches and assessment tools and helped them develop scientific processes and professional skills. However, some participants remarked that microteaching caused stress and anxiety.

The first part of the second research question addressed the effect of the OTPDP on STEM lesson planning. Participants stated that the OTPDP helped them recognize their weaknesses and strengths, plan their lessons better, and integrate technology into their lectures. They also noted that the OTPDP encouraged them to adopt different perspectives, exchange ideas, and use different methods/techniques. In short, the OTPDP affected STEM lesson planning positively, resulting in PD.

The second part of the second research question addressed the challenges of STEM lesson planning and participants' solutions. Participants stressed that they had difficulty planning lessons because they knew little about STEM fields. Teachers with gaps in their content and pedagogical knowledge are more likely to have difficulty planning lessons (Karamustafaoğlu & Özmen, 2004; Srikoom, 2020). Therefore, teachers should first acquire enough content knowledge of a STEM field to be able to draw up a lesson plan tailored to that field (Kırıkkaya, 2009). Participants also pointed out that they had difficulty planning STEM lessons because of limited time and resources. They believed that they could overcome those problems by reading more and working with colleagues more. Wang et al. (2011) also stated that teachers of different STEM fields should work together to integrate those fields into their lectures. Our results are consistent with the literature (Lederman & Niess, 1997; Stohlmann et al., 2012; Wang et al., 2011; Yıldırım, 2020b).

The third part of the second research question focused on what kind of things participants considered while drawing up STEM lesson plans. Participants took STEM fields, 21st-century skills, different methods/techniques, students' level, and target goals into account. They also made sure that the STEM lesson plans were applicable and relatable. Atik Kara and Sağlam (2014) stated that teachers paid attention to level-appropriateness, time, and applicability when planning lessons. Yıldırım (2020b) also claimed that teachers made sure that their lesson plans were relatable and tailored to STEM fields.

The third research question looked into the effect of the OTPDP on STEM teaching. Participants drew up lesson plans and then revised them based on feedback. The first and revised (second) lesson plans were compared. The results showed that the OTPDP improved their STEM pedagogical content knowledge and technological literacy. Research has shown that OTPDPs improve teachers' pedagogical and content knowledge (Bragg et al., 2021; Healy et al., 2020; Polly & Martin, 2020). Moreover, participants had difficulty setting goals and choosing subjects in their first lesson plans, but they did not have those problems in their second lesson plans. Besides, they had no problems integrating the subjects of EID, STMT, GLA, REDL, APP, and SAT into their second lesson plans. This result suggests that the OTPDP improved their ability to teach STEM fields. Research has also shown that OTPDPs help teachers develop professional skills (Powell & Bodur, 2019; Dash et al., 2012; Dede et al., 2009). For example,

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OTPDPs improve preschool teachers' ability to teach math (Sheridan & Wen, 2021) and integrate technology into their lectures (Ching & Hursh, 2014).

The fourth research question addressed participants' perceptions of the impact of OTPDPs in STEM education on teacher employment. All participants noted that OTPDPs in STEM education helped teachers develop the skills that would make them more likely to be employed in the future. Research has also shown that STEM education positively affects employment (Grigorescu et al., 2020; Mattoo et al., 2008) because teachers who receive STEM education are more likely to meet job requirements (Thomas & Lonobile, 2021). Teachers who receive STEM education do not need occupational mobility because they meet job requirements much more than those who do not receive STEM education (Yang, 2018). Therefore, STEM education is critical for teacher employment. Our results were consistent with the literature.

Conclusions and Implications

Teachers attend OTPDPs for professional improvement because they find them flexible, affordable, and accessible. They think that OTPDPs help them acquire professional knowledge and develop professional skill sets. To them, OTPDPs should be flexible, interactive, and quality-content programs that promote group work, respond to needs, and allow for attendance anywhere, anytime. They think that OTPDP group work, interactive learning, and microteaching, in particular, positively affect technological literacy, communication, collaboration, and experience sharing. However, they face environment- and condition-based problems and propose different solutions to them.

Teachers think that OTPDPs help them plan better STEM lessons. Moreover, when they plan STEM lessons, they pay attention to content knowledge, applicability, student level, and relatability. However, they deal with some problems when planning STEM lessons. For example, they lack enough resources and have difficulty managing time and integrating technology and engineering into lesson plans. They come up with different solutions to those problems.

Online teacher professional development programs promote STEM teaching. They mainly help teachers acquire pedagogical content knowledge and develop technological literacy and skills.

Online teacher professional development programs in STEM education positively affect teacher employment.

Limitations

This study had five limitations. First, the results are sample-specific. Therefore, future studies should recruit people from different cultural backgrounds and fields of expertise. Second, participants tended to express positive opinions probably because they were already interested in online learning. Third, the study lasted only five months, and therefore, future studies should be longer in duration. Fourth, the study focused on improving teachers' professional skills regarding STEM education. Fifth, the study focused only on lesson plans, videos, and interviews (qualitative data sources) to determine the impact of OTPDPs on professional development.

Implications for Further Research

The results indicate that OTPDPs improve teachers' professional development, STEM knowledge, and technological literacy. Therefore, teachers should be provided with well-designed OTPDPs to help them develop professional skills. OTPDPs also improve their ability to teach STEM fields, suggesting that OTPDPs should be used to make STEM education more common and effective. This was a five-month study. However, the longer the OTPDPs in duration, the better they are at helping teachers develop professional skills. The lectures were videotaped, which is helpful for teachers as they can catch up with classes. Therefore, recorded lectures should be included in the process.

At the beginning of the OTPDP, teachers had difficulty adapting to online education and using technology and integrating it into their lesson plans. However, as they got used to the process and learned more about it, they overcame those problems and developed technological literacy. This result indicates that developers of OTPDPs should identify teachers' technological self-efficacy levels to fill in the gaps in their knowledge and involve them in the process.

The principles and standards in the literature were followed when creating an OTPDP, and positive results were achieved. This suggests that developers who take those principles and standards into account are likely to develop effective OPDPs. OPDPs should be long-term, flexible, and interactive programs that facilitate technologi-

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cal literacy, respond to attendees' needs, and have theoretical and applied content that promotes microteaching. Teachers who attend OTPDPs mostly have to deal with Internet and infrastructural issues. Therefore, such problems should be resolved before the onset of OTPDPs.

Competing interests

The authors declare no conflict of interest.

Authors' contributions

All authors contributed to the data collection, analysis, and writing of the paper. The author(s) read and approved the final manuscript.

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