İSTANBUL UNIVERSITY CERRAHPAŞA

HAYEF: Journal of Education, 21(3); 258-265

DOI: 10.5152/hayef.2024.23099

Received: November 17, 2023
Revision Requested: December 26, 2023
Last Revision Received: January 7, 2024
Accepted: January 18, 2024
Publication Date: August 6, 2024

HAYEF: Journal of Education

RESEARCH ARTICLE

The Effects of Online Chemistry-Themed Design-Based STEM Education on Preservice Science Teachers' STEM Awareness

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Abstract

The study investigated the impact of Chemistry-Focused Online Science, Technology, Engineering, and Mathematics (STEM) teacher education on the awareness of STEM among preservice science teachers. A one-group pretest–posttest quasi-experimental weak design was used to determine changes in preservice teachers' STEM awareness. During the study, a 14-week Chemistry-Focused Online STEM course was provided to preservice science teachers. As part of this course, the theoretical knowledge about STEM was explained to students, and afterward, they completed two modules. Furthermore, preservice teachers also developed their chemistry-themed STEM lesson plans at the beginning of the course, after explaining theoretical knowledge about STEM at the end. The study group consisted of 17 senior preservice science teachers enrolled in the elective Teaching Chemistry in Elementary Education at a state university in the Marmara region during the spring semester of 2020–2021. The data were collected with the STEM Awareness Scale. The results revealed that chemistry-focused online STEM education enhances preservice science teachers' STEM awareness. Potential implications from this research suggest that the preservice science teacher participants benefited significantly from chemistry-focused online STEM education while engaging in science and engineering practices and using chemistry knowledge to solve real-life problems.

Keywords: Chemistry education, design-based learning, online STEM education, preservice science teacher, STEM awareness

Introduction

We live in an information age where everybody needs to have a vast knowledge of various fields, including science, mathematics, economics, and geography, and should be capable of thinking critically. People must know how to use information technologies and work with people from different sociocultural backgrounds. They must also be creative individuals open to new ideas and opinions. Science, Technology, Engineering, and Mathematics (STEM) education has been a popular method for helping students develop these skills named 21st-century skills (e.g., problem-solving, cooperation, etc.) by integrating STEM disciplines. STEM education provides students with engaging and motivating learning settings where they can practice these skills (Wang et al., 2011). STEM education offers students different advantages while working as STEM professionals. For instance, students participate in experiments, projects, and real-world problem-solving, mirroring the approach of STEM professionals. STEM education equips students with the skills and knowledge needed for careers in STEM fields. Students learn to adapt to new technologies and methodologies, preparing them for dynamic and changing work environments (Aschbacher et al., 2010).

To successfully implement STEM education in the classroom, teachers should be equipped with skills and knowledge of how to teach STEM content to the students and should develop deep STEM content knowledge (Dare et al., 2018; Fischer et al., 2018). Therefore, teachers should partake in-service training programs to acquire knowledge and develop skills related to STEM education. Moreover, preservice teachers should gain the necessary knowledge and experiences and develop skills related to STEM education as undergraduates. Both in-service training programs and undergraduate courses should assist educators in integrating the four STEM disciplines and acquiring a practical understanding of STEM approaches. By combining both in-service training programs and undergraduate courses, educators may benefit from a synergistic educational experience that blends theoretical knowledge with practical applications. This dual approach enhances their readiness to tackle the challenges of STEM professions, fostering a holistic understanding of the interconnected nature of STEM (Dare et al., 2018). However, teachers may employ student-centered methods and approaches in their lectures due to perceived incompetence in STEM education for several reasons.

First, teachers may not have received adequate training in STEM methodologies and practices during their own education. Second, limited access to resources, such as STEM-specific teaching materials, equipment, and technology, may hinder teachers from implementing engaging STEM activities. Third, some teachers may feel uncomfortable or apprehensive about using technology in their teaching, particularly if they have not been exposed to it extensively. Fourth, the demands of covering a broad curriculum within a limited time frame may lead teachers to prioritize content delivery over adopting more time-consuming STEM teaching strategies (El-Deghaidy et al., 2017). Therefore, we

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Cite this article as: Şahin-Topalcengiz, E., & Acar-Şeşen, B. (2024). The effects of online chemistry-themed design-based STEM education on preservice science teachers' STEM awareness. *HAYEF: Journal of Education*, 21(3), 258-265.

should provide teachers and preservice teachers with the opportunity to develop the skills necessary for implementing STEM education in classrooms. Research shows that preservice teachers harbor negative perceptions and possess a limited awareness of their competence in STEM education (Arslanhan & İnaltekin, 2020; Şahiner & Koyunlu Ünlü, 2022). Different researchers have indicated that training programs help preservice teachers become more aware of STEM education, making them more competent in implementing STEM activities (Arslanhan & İnaltekin, 2020; Gökbayrak & Karışan, 2017). Since teachers and preservice teachers are not very good at putting STEM skills into practice (Marginson et al., 2013), we believe that we need to provide them with in-service and preservice training programs to help them grasp the nature of STEM fields and integrate them accurately in their lectures (Akaygun & Aslan-Tutak, 2016; Dare et al., 2018; Dare et al., 2019; Radloff & Guzey, 2016; Sahin-Topalcengiz, 2022; Vossen et al., 2020).

STEM education involves various approaches, such as problem-based, project-based, or design-based learning (Capraro et al., 2013; Hynes et al., 2011). Design-based learning in STEM education fosters a hands-on, project-oriented approach where students engage in real-world problem-solving and design challenges within the fields of STEM. Design-based learning allows learners to integrate engineering with science, math, and technology (Gómez Puente et al., 2011). Engineering is interdisciplinary. Therefore, engineers use their knowledge and skills in science, technology, and mathematics to solve real-life problems (Lachapelle & Cunningham, 2014). Design-based learning allows learners to work as engineers, familiarizing them with different branches of engineering and their working principles while gaining a solid understanding of science, engineering, and mathematical processes and concepts. This journey makes them more interested in STEM fields (Mehalik et al., 2008; Sadler et al., 2000; Mehalik et al., 2008). Design-based learning encourages learners to practice 21st-century skills (creativity, problem-solving, and cooperation) (Chandrasekaran et al., 2015). This study focused on design-based learning because it is superior to other approaches in some ways.

Design-based learning is also referred to as "learning by design" (Kolodner et al., 2023), which is rooted in case-based learning and problem-based learning (Gómez Puente et al., 2011; Kolodner, 2002; Şahin Topalcengiz, 2022). Design-based learning enables students to acquire scientific knowledge and collaboratively address problems through research and inquiry in groups. Design-based learning is a learner-centered approach that helps students learn science concepts and design new products through engineering design processes (Chandrasekaran et al., 2015; Gómez Puente et al., 2013; Kolodner et al., 2003). Researchers suggest that educators should adopt design-based learning and use different models to teach science concepts (Fortus et al., 2005; Frey & Powers, 2012; Kolodner et al., 2014; Wendell et al., 2010). For instance, Wendell et al. (2010) developed a model that puts engineering designs at the center and involves processes regarding adaptation to the course (Figure 1). Teachers can utilize this model to instruct students in designing things based on scientific concepts, guiding them through a cycle that relates to their surroundings (Wendell et al., 2010; Ercan, 2014).

Design-based learning consists of various engineering design process steps, including 1) defining problems, 2) finding solutions, 3) evaluating solutions, 4) improving, testing, and evaluating solutions, and 5) communicating (Brunsell, 2012). Hynes et al. (2011) proposed a nine-step cycle for learners at the high school level and above (Figure 2).

In this cycle, students first identify problems and determine the necessary elements for solutions. Second, they do research to identify what they know and what they need to learn for designs tailored to solutions. Third, they brainstorm to propose different solutions. Fourth, they consider criteria and limitations when choosing the most appropriate solution. Fifth, they build prototypes. Then, they test their prototypes just like engineers test their solutions in real life and identify the successes and weaknesses of their solutions. Sixth, they present their prototypes to their classmates and improve them based on their feedback. Lastly, they decide whether their prototypes are the best solutions. It's important to note that the steps of the engineering design process are not strictly linear. Teachers and preservice teachers should follow this cycle to learn how to develop products and processes (Cunningham & William, 2014). This study has adopted the model of Hynes et al. (2011), which allows for a detailed experience and understanding of engineering design processes.

Most researchers have concentrated on concrete physics concepts to investigate the impact of in-service and preservice STEM training programs (Arslanhan & İnaltekin, 2020; Capobianco et al., 2022; Cavlazoglu & Stuessy, 2017; Christian et al., 2021; Lesseig et al., 2016).

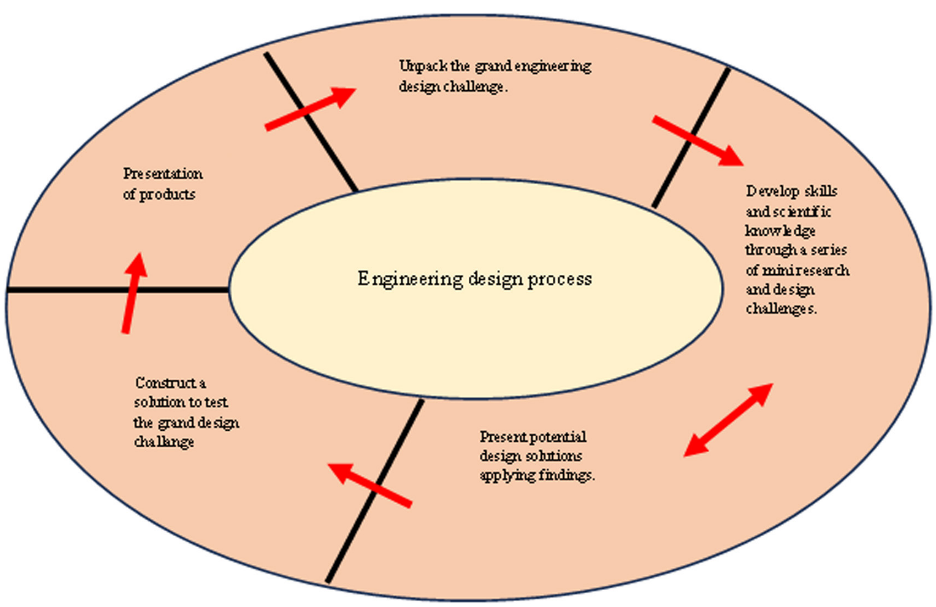

Figure 1.
Design-Based Science Learning (Wendell et al., 2010).

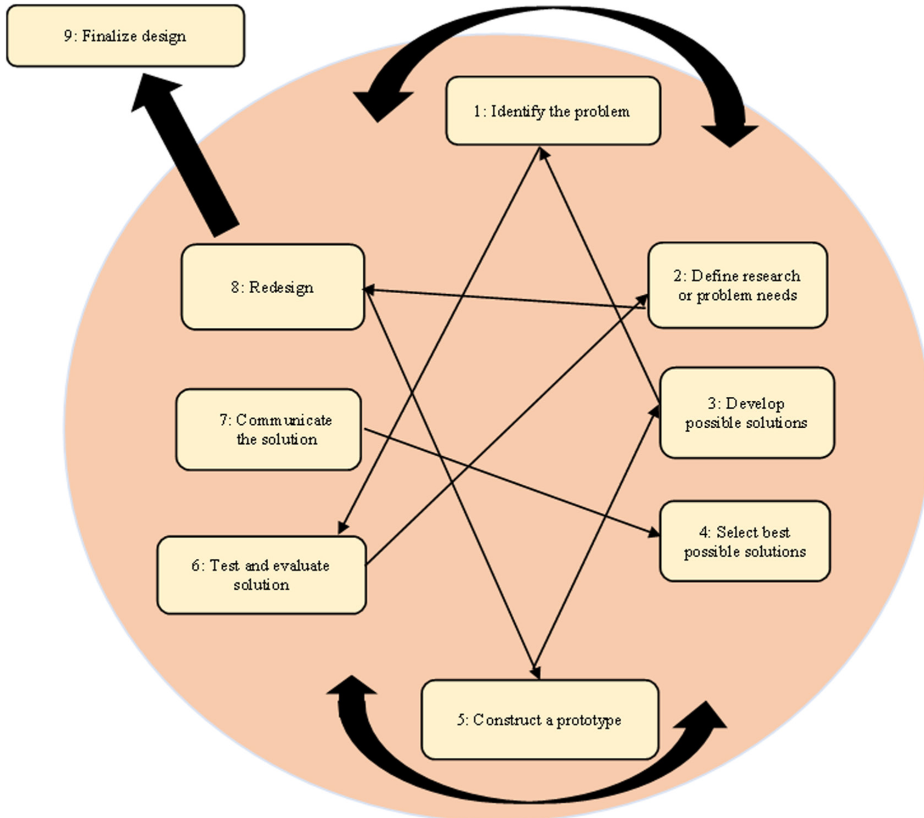

Figure 2.
Engineering Design Process (Hynes et al., 2011, p. 9).

Students interested in pursuing a career in STEM should take chemistry and related courses. Students find chemistry courses challenging and dull because they struggle to perceive chemistry concepts through their five senses. However, they tend to understand these concepts primarily at a mental level as they are taught in science courses (Eilks & Hofstein, 2015). Teachers employ teacher-centered methods of teaching to teach chemistry concepts. They focus on chemistry topics and concepts separately, yet they ignore or put less emphasis on core ideas and cross-cutting concepts (McGill et al., 2019). Students often resort to memorizing chemistry concepts as teachers employ methods and techniques that make the learning experience passive (Martinez et al., 2021; McGill et al., 2019). Therefore, students have difficulty connecting chemistry concepts to sub-disciplines of chemistry, other academic disciplines, and daily life (De Jong & Taber, 2014). For example, undergraduates learn thermodynamics within the scope of the "General Chemistry" course. However, many biochemical reactions also occur according to the rules of thermodynamics (Martinez et al., 2021). Most students who have taken the "General Chemistry" course find it difficult or impossible to relate entropy to osmosis (Martinez et al., 2021). Teachers should relate chemistry concepts to sub-disciplines of chemistry and other disciplines (De Jong O & Taber, 2014; Karpudewan & Huri, 2023; McGill et al., 2019). For instance, companies apply the principles of electrochemistry to manufacture more eco-friendly batteries that are safe for human health (Karpudewan & Huri, 2023). Students adopt interdisciplinary approaches to solve everyday life problems and use electrochemical and mathematical principles to design products (Karpudewan & Huri, 2023). While teachers relate chemistry concepts to various disciplines, students learn how to apply knowledge and skills from different fields (Hardy et al., 2021). The Sustainable Development Goals (2030) set by the United Nations also recommend integrating chemistry with other disciplines to solve current problems (Hardy et al., 2021). For example, the United Nations set the goal of "ensuring availability and sustainable management of water and sanitation for all" in line with the 2030 Sustainable Development Goals. The objective is to develop eco-friendly and cost-effective water filtration methods (Hardy et al., 2021), which require the involvement of chemistry (Hardy et al., 2021). Integrating chemistry with other disciplines to address regional, national, and international issues necessitates shifting how we approach chemistry teaching (Hardy et al., 2021). Therefore, we should use student-centered approaches such as STEM to teach chemistry. However, only a few researchers have addressed teaching chemistry concepts through STEM (Aydın-Gunabatar et al., 2022; Aydın-Gunabatar et al., 2020; Baydere et al., 2020; Coskun Karabulut et al., 2023; Dare et al., 2019). Therefore, two chemistry-themed online modules were developed for preservice teachers for this study. Online STEM education was considered suitable for the study due to factors such as time constraints, limitations in materials, and a deficiency in student competencies (Chen et al., 2018; Eroğlu & Bektaş, 2016).

There are two types of online STEM education programs: synchronous and asynchronous. Online STEM education programs incorporate approaches that empower students to actively engage in the learning process and utilize digital tools associated with everyday life (Barril, 2018; Chen et al., 2018). Online STEM courses include learning resources, such as videos and simulations. Teachers also use different methods to assess their students regularly (Chen et al., 2018; Dipietro et al., 2008). STEM courses include face-to-face and online communication pathways (such as Zoom and discussion forums) to enable students to interact with their peers and instructors (Chen et al., 2018; Mostacedo-Marasovic et al., 2022). Online STEM education programs provide equality of opportunity by allowing students to attend classes anywhere, anytime (Delen, 2021; Simonson et al., 2015). The advantages of online STEM education programs indicate the importance of providing online STEM education opportunities to preservice teachers. Therefore, this article focuses on a design-based and chemistry-oriented online STEM training program that would allow preservice teachers to actively participate in the learning process based on everyday life problems. This study investigated whether the program would make preservice science teachers more aware of STEM education.

Methods

The study adopted a single-group, pretest–posttest quasi-experimental research design (Büyüköztürk, 2007) to investigate whether the chemistry-focused integrated STEM training program raised participants' awareness of STEM fields. Researchers who employ single-group, pretest–posttest quasi-experimental research designs focus on one group to address the effect of an independent variable on a dependent variable (Creswell, 2012). While single-group, pretest–posttest experimental designs are considered weak designs, they are often used to develop and implement training programs or curricula (Creswell, 2012). Therefore, this study adopted a single-group, pretest–posttest quasi-experimental research design to investigate whether the chemistry-focused integrated STEM training program raised preservice teachers' awareness of STEM fields.

Sample

The sample consisted of 17 preservice science teachers (4 men and 13 women) from the Department of Science Education of a public university in the Marmara Region. The preservice science teachers were purposely selected because they had taken field courses (such as general physics, general chemistry, and general biology), pedagogy courses (such as teaching principles and methods, science learning and teaching approaches, and science teaching programs), and general culture courses (such as foreign language, computer) that form the basis of the STEM training program in question. Four participants were 21 years old (23.5%). Six participants were 22 years old (35.3%). Five participants were 23 years old (29.4%). One participant was 24 years old (5.9%). One participant was 32 years old (5.9%). The study was approved by the Social and Humanities Research Ethics Committee of İstanbul University-Cerrahpaşa (Approval no: E-74 555795-050.01.04-29654, Date: 11.02.2021). Permission was obtained from the dean of the faculty of education (Approval no: E-44949735-604.01.02-45241). Participants were recruited using convenience sampling, which is a cost- and time-effective method that allows researchers to quickly and affordably gather data from readily available subjects, often chosen for their accessibility or proximity to the researcher (Büyüköztürk et al., 2014). All preservice teachers were informed about the purpose of the research and its procedure. Informed consent was obtained from those who agreed to participate in the study.

Data Collection Tools

The data were collected using the STEM Awareness Scale as a pretest and posttest instrument.

Science, Technology, Engineering, and Mathematics Awareness Scale

The STEM Awareness Scale (SAS) was developed by Çevik (2017). The instrument consists of four negative and eleven positive items rated on a 5-point Likert-type scale (1: Strongly disagree; 2: Disagree; 3: Undecided; 4: Agree; 5: Strongly agree). The scale has a Cronbach's alpha (α) score of .82. The instrument has three subscales: (1) the effect on students ($\alpha = .81$), (2) the effect on class ($\alpha = .71$), and (3) the effect on teachers ($\alpha = .70$). The original scale was prepared for secondary school teachers. However, the researchers decided it could also be suitable for preservice science teachers. Two experts conducting research in the field of STEM and one expert working in the field of science education were consulted for content validity. They concluded that the scale was suitable to use with preservice science teachers.

Research Design

The research was conducted within the scope of the "Primary School Chemistry Teaching" elective course in the spring semester of 2020–2021. The research was performed synchronously (Zoom) and asynchronously using different information and communication technology (ICT) tools (e.g., Padlet, YouTube, Zoom, Google Classroom, etc.) for 14 weeks. Table 1 shows the course content.

In the first week, the researchers informed all participants on the course syllabus and administered the pretest. In the second week, they addressed the following topics: the definition and historical development of STEM, STEM literacy, 21st-century skills, and STEM in the Turkish Science Curriculum. In the third week, engineering and engineering design processes and models were introduced. In the fourth and fifth weeks, they discussed various STEM approaches, methods, and techniques, and sample STEM lesson plans were presented to them. In the sixth week, they provided information on design-based STEM and assessment and evaluation in STEM. In the eighth week, all participants participated in the modules tailored to the design-based online STEM training program. Two modules were developed for the program: (1) designing a water filter and (2) designing a toothpaste. The first module consisted of two mini-design investigations ((1) determining the water quality of water basins and (2) determining the water footprint of the Kızılırmak delta) and a grand design challenge (Designing a Water Filter for Kızılırmak). The second module consisted of two mini-design investigations (Structure of the teeth and dental

Table 1.
Content of the Online Design Based Chemistry Themed Science, Technology, Engineering, and Mathematics Course

Week	Content
1	Introduction to the course, conducting pretest, STEM lesson planning
2	Definition of STEM, history of STEM education, STEM literacy, 21st century skills, STEM in Turkish science education curriculum
3	Engineering, engineering design process, and different engineering design models
4	Different approaches, methods, and techniques used in STEM education (project-based STEM, problem-based STEM, STEM SOS, inquiry-based STEM)
5	Different approaches, methods, and techniques used in STEM education (context-based STEM, mastery learning for STEM), different approaches to integrate STEM disciplines
6	Design-based STEM, assessment in STEM education, STEM lesson planning
7	Mid-term exams
8	Mid-term exams: assignment of grand design problem 1 Mini investigation 1: determining the water quality of water basins
9	Discussions about mini-investigation 1, mini investigation 2 (determining the water footprint of the Kızılırmak Delta) and assigning grand design challenge (designing a water filter for Kizilirmak)
10	Discussions about mini investigation 2 and grand design challenge; Presentations of mini investigation2 conclusion of grand design challenge 1 Introducing grand design challenge 2 (toothpaste production)
11	Discussions about possible solutions of great design challenge 2; discussions about mini investigation 1 (structure of the teeth and dental health); assigning mini investigation 2
12	Discussions about mini investigation 2 (Exploring the effect of acidic drinks on dental health); presentation of candidates' controlled experiments
13	Discussions about grand design challenge 2; presentation of preservice teachers' grand designs.
14	Conducting posttest

Note: STEM = Science, technology, engineering, and mathematics.

health, Exploring the effects of Acidic Drinks on Dental Health) and a grand design challenge (toothpaste production). In the ninth week, the researchers introduced all participants to the problem regarding the great design within the scope of the "Designing a Water Filter" module. Students were asked to identify the concepts they would use to solve the problem. The first design challenge, "determining the water quality of water basins," was also presented to the students. The participants completed the first challenge before the online class. They also shared the worksheets given for the first design challenge and problem identification with the instructors and course members under the assignment title in Google Classroom on the due date determined in the course syllabus. After each design task, the instructors reviewed the worksheets and provided feedback. They also discussed the problem and the first design task with the participants on Zoom. During class, they asked all participants questions, including "What does Nevşehir Hacı Bektaş Veli University Environmental Engineering require from you?" and "What scientific concepts do you need to know to design a water filter?" The purpose of the questions was to get the participants to think about the concepts they needed to know to solve the problem. The instructors also posed questions, including "What is a river basin?" "For what purposes do we use water resources?" "What determines water quality in river basins?" "Why is water in river basins polluted?" "What is wastewater?" Can we turn wastewater into water suitable for drinking and using? "How do different activities (e.g., agriculture and livestock, industry, recreational activities) affect the water quality of rivers?" The purpose of these questions was to get the participants to discuss the changes in different characteristics of water, such as pH and temperature. In the tenth week, all participants completed the mini design challenge (determining the water footprint of the Kızılırmak delta) and the grand design challenge 2 (designing a water filter for Kızılırmak) before class. During class, the researchers held discussions first with small groups and then with all participants on Zoom breakout rooms about the following topics: geographical activities of Kızılırmak delta, species in Kızılırmak delta, the effect of soil structure and geological characteristics of the Kızılırmak delta on the amount of water in the delta, seasonal changes in water resources, uses of water resources, the impact of crops cultivation on water quality, the impact of animal husbandry on water resources. All participants presented their action plans regarding the conservation of Kızılırmak delta. They also video-recorded and photographed their solutions to grand design problems, prototyping, testing, and redesign phases. During class, the researchers held discussions with participants about their solutions. Then, they presented the videos and photos of the prototypes and asked the participants to come up with solutions. In the tenth week, the researchers assigned the grand design problem and the module's first mini-design challenge (structure of teeth and dental health), "Toothpaste production." In the eleventh week, all participants held discussions on Zoom about the scientific concepts they were to use to solve the problem. During class, the researchers held discussions first with small groups and then with all participants in Zoom breakout rooms about the following questions: "What is the structure of a tooth?" "Why does a tooth decay?" "What are the parts of a tooth?" "Do protein, fat, and carbohydrates cause tooth decay? If so, how?" "How can we protect our oral and dental health?" "Why do we use toothpaste?" "What is the content of toothpaste?" "What are the chemicals in toothpaste used for?" "In what proportions are the active ingredients in toothpaste?" All participants used their knowledge of chemistry and biology to explain the structure and parts of a tooth, the impact of foods on oral and dental health, oral chemistry, and tooth decay. In the twelfth week, before class, all participants completed the second mini-design challenge (Exploring the Effect of Acidic Drinks on Dental Health). Within the scope of this challenge, they designed an experiment showing the impact of various beverages on dental health. They determined ten beverages' pH values and sugar content (orange juice, lemonade, water, sparkling water, Coca Cola, etc.). Then, the participants put eggshells in the beverages. They made observations for a few days and noted their observations. They also video-recorded, photographed, and presented the whole process in the classroom. During the online class, the researchers talked to the participants about their experiments, and the participants presented their experiments and results. They held discussions with the participants to get them to understand the impact of nutrition on dental health and oral chemistry. In the thirteenth week, before class, all participants completed the mission of developing an organic and low-cost toothpaste that tastes good for people who consume very high amount of tea and coffee. They shared the pictures, videos, and worksheets of the toothpaste development and testing process with the instructors under the relevant assignment title in Classroom. During class, the researchers held discussions first with small groups and then with all participants in Zoom breakout rooms about the ingredients of the toothpaste, their functions, and the chemistry of teeth whitening. The researchers presented photos and videos of the toothpaste formulations to get the participants to associate the topics of pH and redox reactions they addressed when they discussed the development of toothpaste and teeth whitening. In the last week, the researchers administered the posttest. Preservice science teachers developed chemistry-themed STEM lesson plans before the training, at the end of the STEM theoretical training, and after completing STEM activities.

Data Analysis

The data were analyzed using the Statistical Package for the Social Sciences (IBM, SPSS v. 20). Normality was tested using the Shapiro–Wilk test. Normality was also checked based on histogram graphs, skewness, and kurtosis values. The kurtosis values for the pretest and posttest were −1.035 and −.355, respectively. The skewness values for the pretest and posttest were −.071 and −.355, respectively. Since the skewness and kurtosis values were within the range of −1.5 to +1.5, it indicated that the data were normally distributed (Pituch & Stevens, 2016). The Shapiro–Wilk test result was .445 for the pretest and .687 for the posttest, indicating that the data were normally distributed (Büyüköztürk, 2015). Therefore, the data were analyzed using the *t*-test, which is a parametric test.

Results

This section addressed the results regarding the impact of the online chemistry-focused integrated STEM teacher training program on preservice science teachers' STEM awareness.

The results showed that participants had a significantly higher mean posttest SAS score than the pretest score ($t(16) = -4.85$. $p < .05$) (Table 2). This result showed that the online design based chemistry-focused integrated STEM teacher training program increased all participants' awareness of STEM. Cohen's *d* (1.17) also indicated the effect size of the intervention on participants.

Discussion

This study investigated the effect of an online chemistry-focused design-based integrated STEM teacher training program on preservice science teachers' awareness of STEM. The results showed that participants had a significantly higher mean posttest SAS score than the pretest score. This result indicated that the training program raised all

Table 2.
T-Test Results for Pretest and Posttest STEM Awareness Scale Scores

Scale		*N*	*X*	*S*	SD	*t*	*p*
SAS	Pretest	17	60.12	4.71	16	−4.85	.000
	Posttest	17	64.94	4.20			

Note: SAS = STEM Awareness Scale; STEM = Science, Technology, Engineering, and Mathematics.

participants' awareness of STEM, which is consistent with the literature (Akgün & Türel, 2021; Arslanhan & İnaltekin, 2020; Christian et al., 2021; Gökbayrak & Karışan, 2017; Kewalramani et al., 2022; Kim & Bolger, 2017; Şahin & Hacıömeroğlu, 2021; Şahiner & Ünlü, 2022). Gökbayrak and Karışan (2017) found that STEM activities increased preservice science teachers' awareness of STEM. Şahiner and Ünlü (2022) reported that activities regarding engineering design processes increased preservice classroom teachers' awareness of STEM. Arslanhan and İnaltekin (2020) documented that design-based STEM activities nurtured preservice science teachers' awareness of STEM and made them feel more competent in STEM education. Watson et al. (2022) argued that teachers and preservice teachers' awareness of STEM is affected by different factors, including 1) participating in STEM training programs (Aydin-Gunbatar et al., 2018; Watson et al., 2022), 2) STEM curricula and activities (Watson et al., 2022), 3) experience in preparing STEM lesson plans (Kim & Bolger, 2017).

Preservice and in-service training programs focusing on integrating STEM education and problem-solving activities make learners more aware of STEM disciplines (Watson et al., 2022). Therefore, the researchers of the present study first provided preservice science teachers with theoretical training on STEM education and its importance, engineering, engineering design processes, and design-based STEM. Then, participants found solutions to daily-life problems. The results showed that the online chemistry-focused design-based integrated STEM teacher training program helped all participants become more aware of STEM fields. Participants also developed chemistry-themed lesson plans before the training, at the end of the theoretical training, and after completing STEM activities. The researchers gave feedback to the participants to provide them with rich learning content to effectively and accurately link chemistry concepts with engineering, technology, and mathematics disciplines (Kim & Bolger, 2017). The feedback helped them relate STEM disciplines to everyday life and develop lesson plans appropriate to the grade level. Kim and Bolger (2017) also had preservice teachers develop STEAM lesson plans. They found that the intervention helped the participants become more aware of STEM fields and associate STEAM fields effectively and accurately in their lesson plans.

It is important for teachers and preservice teachers to have awareness of STEM fields, and their awareness depends on their access to STEM curricula and activities (Watson et al., 2022). They use STEM curricula and activities when creating STEM-based lesson plans (Watson et al., 2022), so it is crucial to ensure that they have access to accurate and effective STEM curricula and activities (Watson et al., 2022).

Conclusion and Recommendations

This study investigated whether an online chemistry-focused design-based integrated STEM teacher training made increased the awareness of STEM among preservice science teachers. Research shows that preservice teachers who develop STEM lesson plans become more aware of STEM. However, although the participants developed lesson plans, this study did not investigate the relationship between STEM awareness levels and STEM lesson planning skills. Therefore, further research should investigate the possible relationship between teachers' awareness level and STEM lesson planning skills.

Preservice teachers consider themselves incompetent in STEM education (Banilower et al., 2018). Therefore, we should provide preservice science teachers online and face-to-face STEM learning opportunities to gain experience in engineering design processes while integrating STEM disciplines. The focus of this study was on an integrated STEM teacher training program that emphasizes design-based learning. Future studies should investigate the effects of different online learning modules on preservice teachers' STEM awareness. While online training programs are time- and cost-effective techniques that are easily accessible, participants have difficulty taking part in them because they may face technical problems, have inadequate technology literacy, and suffer from a lack of motivation (Şahin-Topalcengiz & Yıldırım, 2020). Therefore, researchers should address online training programs' positive and negative dimensions and their effect on pre-service teachers' STEM awareness.

This study has two limitations. First, a single-group, weak experimental design was adopted to investigate how an online chemistry-themed integrated STEM teacher training program affects preservice science teachers' STEM awareness. Researchers should recruit students from different grade levels and majors to examine the program's effect on their STEM awareness. Researchers from other countries should also replicate this study and address the impact of online STEM education on pre-service teachers' STEM awareness. Second, the sample consisted mostly of female students. Therefore, it is advisable for future researchers to ensure equal representation of both genders in their research designs.

Availability of Data and Materials: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of İstanbul University-Cerrahpaşa (Approval no: E-74555795-050.01.04-29654, Date: 11.02.2021).

Informed Consent: Written informed consent was obtained from participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – E.Ş.T., B.A.Ş.; Design – E.Ş.T., B.A.Ş.; Supervision – B.A.Ş.; Resources – E.Ş.T., B.A.Ş.; Materials – E.Ş.T., B.A.Ş.; Data Collection and/or Processing – E.Ş.T.; Analysis and/or Interpretation – E.Ş.T., B.A.Ş.; Literature Search – E.Ş.T.; Writing Manuscript – E.Ş.T., B.A.Ş.; Other – E.Ş T.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

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