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The Effect of a STEM Education Workshop on Science Teachers' Instructional Practices

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ABSTRACT

Interdisciplinary STEM education is a particular pedagogical methodology in which learners learn the association and connection of the knowledge of science and mathematics through particular technological engineering. To achieve this, specific interdisciplinary STEM-based educational curricula should be developed, and teachers should be qualified appropriately before any implementation process. Therefore, the aims of the research are both to (a) reveal the effect of the STEM workshop on science teachers' awareness of the relationship between science and other disciplines and to (b) examine its transferring contribution to their lesson planning approach. The case study method was used to get the essential data of research with 40 science teachers. The data were gathered via the Questionnaire for Interdisciplinary Association of Science, the lesson plans, and semi-structured interviews. As a result of the research, less variation is found in disciplines associated with science such as mathematics, technology-design, social studies, engineering, visual arts, Turkish languages, and music, etc. compared to data tools that they applied before and after workshop sessions. Besides, the post-applied data tool results revealed that the participants provided more comprehensive explanations regarding the direction of the interdisciplinary association, which suggests a better understanding of the relationship of science with other disciplines in the latter case. In addition, it was determined that most of the teachers designed their lesson plans based on an interdisciplinary approach and used the Engineering Design Process (EDP) as a teaching method to create the learning environment.

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Introduction

In technological societies, vital factors such as expected and required knowledge and skills from individuals have been differentiated and concentrated. In this sense, it is no longer enough to learn information; rather, learned information must be an instrument for arousing creativity, innovativeness, entrepreneurship, and leadership skills of individuals (Burkhardt et al., 2002). Furthermore, it is not plausible to expect the acquisition of all these skills under the roof of one single academic field. Instead, it can be possible through an interdisciplinary approach, which lifts borders among various disciplines, thus allowing exposure to multiple disciplines at one time. The idea of the interdisciplinary approach first emerged when educators noticed that school subjects are taught in isolation from real-life problems and in many cases, individuals must acquire skills that transcend particular disciplines (Karatas, 2018; Roehrig et al., 2012). People often tend to perceive the outside world from a holistic perspective. With this mindset, knowledge and skills specific to certain disciplines are transcended every time people attempt to find solutions to problems they face, try to communicate with others, and encounter questions and answers in daily life. Rather, they bring into being a meaningful pattern of several disciplines. Apart from that, the developing and changing science and technology, coupled with the emergence of complex problems with each day, offer new areas of study such as Biorobotics, Biomedical, Energy Systems, Industrial Design, Nanotechnology, 3D Production, and Mechatronics. It would be necessarily difficult to study and teach these fields from the traditional narrow scope of disciplines (Aydeniz, 2017). In developed countries, especially in the United States, studies founded on interdisciplinary approaches are conducted in teacher training curricula at all levels. The fact that the science curriculum depending on an interdisciplinary approach in the USA failed to achieve the desired success, particularly in the 2000s, and thus the business world became deprived of the desired quality of engineers and workers, brought into question the interdisciplinary teaching and dissemination of science, technology, engineering and mathematics (Kelley & Williams, 2013; Yıldırım, 2018). In that setting, engineering was taken as a mediating discipline that integrates mathematics, science, and technology altogether, providing a ground for interdisciplinary learning. As a result, an interdisciplinary approach was proposed which is named STEM (Science, Technology, Engineering, and Mathematics). This new approach was described as a key to stimulating the economy by American politicians and industrialists. The expansion of STEM education became a general policy since then (Lacey & Wright, 2009).

The high degree of importance placed on STEM education opened a new era for addressing a number of important issues such as developing STEM-based curricula in educational institutions, teacher training, and professional development (Cepni & Ormancı, 2018; Farihah et al., 2021). For example, a report titled "Engineering 2020" was released in 2004 and another was released in 2009 with the title of "Engineering in K-12 Education". Those reports put forward a series of guiding results on prospective training policies, curricula, and teacher training activities regarding STEM education to assist politicians and educators. In a resultant way, National Science Foundation developed the existing teaching curricula to improve and disseminate STEM education in the K-12 educational system. One of those curricula is called Next Generation Science Standards [NGSS] (2013), which was designed to speed up the development and research of STEM curriculum not only in the USA but also in the international science education community. Most importantly, the curriculum was designed in an attempt to teach science in such a way that integrates science with engineering and mathematics through an interdisciplinary approach (Ulger & Cepni, 2020).

The NGSS (2013) discussed the impact of many interdisciplinary curricula. It raised the need to develop STEM educational policies and curricula according to the specific needs of countries. Considering these needs, a variety of interdisciplinary STEM curricula were developed such as STEM+C (STEM+Computing), STEM+E (STEM+Entrepreneurship), STEAM (STEM+Art), STREAM (Science, Technology, Reading/Religion, Engineering, Arts, Math), and STEAM GLASS (Science, Technology, Engineering, Arts, Math, Geography, Language Arts, Social Studies) (Akgunduz et al., 2015).

Similarly, Turkey issued significant reports and documents leading to an interdisciplinary STEM education such as Scientific and Technological Research Council of Turkey's [TUBITAK] Science and Technology Development Plan for 2011-2016, The Strategy Report for 2003-2023, "Research Report on Demand and Expectations for Workforce Trained in Science, Technology, Engineering, and Maths" published by Turkish Industrialists' and Businessmen's Association [TUSIAD] (2014), and Ministry of National Education [MoNE]'s "Report on STEM Education" (2016). In the light of these documents and reports, the Ministry of National Education (MoNE) developed a STEM Education Action Plan Recommendation (MoNE, 2016). In this context, program development studies were carried out after the 2000s in Turkey. The science curriculum was placed upon an interdisciplinary understanding, renaming the course as "Science and Technology Curriculum" and the learning field of Science-Technology-Society-Environment (STSE) was associated with STEM in 2013 and then the curriculum was revised to ultimately integrate engineering into the science curriculum as a mediating discipline that combines science, technology, and mathematics as in the NGSS in 2018 (Cepni & Ormancı, 2018). The new version of the curriculum deals with engineering at all learning fields, “Scientific and Engineering Applications” in the domain of knowledge, “Engineering and Design Skills” in the cognitive domain, and “The Relationship among Science, Engineering and Technology” in STSE domain. Considering the relationship between engineering and learning domains of the curriculum, it is considered appropriate to employ new teaching techniques like Engineering Design Process (EDP) (Corlu, 2014; Corlu & Calli 2017).

It is crucial for countries to prepare curricula based on interdisciplinary STEM education if they aspire to achieve their future progress goals. Yet, it does not seem enough without a sufficient number of teachers well trained in STEM areas because highly-qualified teachers constitute the foundation of a feasible STEM-based curriculum (Wang, 2012). This is evidenced in the literature indicating that teachers' beliefs, knowledge, awareness, motivation, skills, and competences play an important role in the success of educational reforms (Cuban, 2004; Felix et al., 2010; Nathan et al., 2011). Mansour (2009) states that since teachers' attitudes regarding the effectiveness and efficiency of a new approach are based on their limited experience with the approach, they often fail to implement and develop new approaches. Previous researches show that teachers are not encouraged to relate their STEM subject areas to other disciplines or they do not have such an experience, so they just try to transfer knowledge to their students about their respective subject ignoring if knowledge and skills learned in those lessons are referred to in other subject areas or whether the knowledge and skills are connected to other lessons (Bers et al., 2013; Kier et al., 2013; Nathan et al., 2011; Park et al., 2017; Samsudin et al., 2020). According to Roehrig et al. (2012), one of the major educational problems of K-12 STEM education is the extremely small number of professional development programs to guide and assist teachers to understand the relationship between STEM disciplines and how to reflect this relationship to their classrooms. Fortunately, following the introduction of the NGSS program in the United States, concrete steps were taken to increase the effectiveness of STEM education in schools. In this scope, several professional development programs were introduced to teachers at science centers such as the Boston Museum of Science, Minnesota Science Museum, New York Science Museum, and Mickelson ExxonMobil Teachers Academy. The most active and popular one, the Boston Museum of Science, runs training courses in engineering and technology especially for K-12 teachers hosted by the “National Centre of Technology Literacy” under its roof. This professional development program includes online courses involving handmade projects and particular workshops applying the curriculum called “Engineering is Elementary” (Hanover Research, 2011).

In the same way, some international organizations were established in many European countries in order to support STEM education in schools and to provide stakeholders with curricular initiatives. Among them, The European STEM Professional Development Centre Network, which is like an official forum of teacher education institutions in the fields of science, maths, and STEM across 12 European countries, and enables sharing of good practices. Besides, individual European countries work to develop STEM education at the national level. For example, the National STEM Centre, founded by the National Science Learning Centre at York University in the UK, trains STEM teachers from various levels of teaching and offers teaching materials and a variety of resources to the beneficiaries (Howarth & Scott, 2014). One more example is the German STEM Teacher Academy, which runs online training for active teachers twice a year. Online training focuses on helping teachers develop instructional materials and use them effectively in the classroom.

In Turkey, a series of activities were planned to improve teachers’ attitudes towards STEM education along with gaining knowledge and skills about STEM (MoNE, 2016). That sort of activity is being carried out by divisions affiliated to the MoNE and also universities in recent years. For instance, the Directorate General of Innovation and Educational Technologies [YEGITEK], one of the directorates of MoNE, took part in the Scientix Project for national support, which is carried out by the European School Network for STEM education with the participation of 30 European countries. In the scope of the Scientix, YEGITEK completed 20 STEM Training Workshops in 18 provinces of Turkey in order to provide the knowledge and skills for teachers from STEM-related subject areas to develop STEM projects targeting secondary schools and vocational and technical education schools. Other workshops are still in progress. Considering that universities follow scientific studies and adjust their curricula accordingly, STEM approaches are placed in curricula of most education faculties and various initiatives are funded by TUBITAK.

The current research was aimed at revealing the effects of a STEM workshop on science teachers in terms of adopting an interdisciplinary science approach and reflecting onto the newly adopted understanding during the preparation of lesson plans. It was intended to find answers to the following questions:

1. How did the STEM workshop affect science teachers' realizing the relationship between science and other disciplines?
2. How did the STEM workshop affect science teachers' transferring the interdisciplinary association to lesson plans?

Methods

The research was conducted as a case study. The research method was preferred to study in-depth a specific variable rather than a number of variables, collecting the data in a systematic way, and figuring out the probable future considerations in the light of the outcomes here (Stake, 1995). Stake (1995) posits that case study research is an investigation and analysis of a single or collective case, which is intended to capture the complexity of the phenomenon being studied. This study was aimed at revealing the effects of the STEM workshop on science teachers in terms of adopting an interdisciplinary science approach and reflecting onto the newly adopted understanding during the preparation of lesson plans. According to Yin (2014) "…single case study may still be incorporated subunits of analyses, so that a more complex (or embedded) design is developed. The subunits can often add significant opportunities for extensive analysis, enhancing the insight into the single case…" (Yin, 2014; p. 56). Therefore, this research was structured according to the embedded single case study design. According to Scholz and Tietje (2002) "…the embedded case design allows for both qualitative and quantitative data and strategies of synthesis or knowledge integration. The methods provided to interrelate and integrate the variables, findings, evaluations, and so on from the various facets of the case or subunits of case inquiry. Thus, the methods of knowledge integration help explain the data under consideration, thereby making data and inferential processes more transparent…" (Scholz & Tietje, 2002, p. 14). In this study, the researchers gathered three types of data collection tools to support the findings of this embedded single-case study: document review (The Questionnaire for Interdisciplinary Association of Science and teachers' lesson plans) and semi-structured interviews.

STEM Workshop Programme

The research was conducted for two-activity periods (Period I: 27 May - 4 June 2016; Period II: 2 - 10 September 2016) for STEM workshops. The sessions of the workshop are given in Table 1.

Table 1

Workshop Sessions

Days	The heading of the session	Content of the session
1st	The nature of the STEM approach Integration of the STEM approach into science education	Learning about the STEM approach. An understanding and knowledge of how to use the STEM approach in science education are acquired.
2nd	Let's learn the engineering design process (EDP) STEM da Vinci workshop (Slopped Stair design)	Awareness is raised about why engineering education should be integrated into science teaching. The steps of EDP are learned. Engineering model design materials are recognized, and the using ability is gained. Knowledge and a positive attitude about how to use the model in the science lessons are acquired.

3rd	Methods used in STEM education 5E learning cycle; Project-based learning; Problem based learning Lesson plan development workshop	Information is given about methods to be used in the integration of STEM education into the science lesson. Knowledge and skills about the science lesson plan development based on STEM education are given.
4th	STEM Statics workshop (Bridge design) Integration of the models into lesson	Knowledge and skills about how to use the STEM approach in teaching statics-equilibrium.
5th	STEM Mechanical workshop (Amusement park high-speed train design) Integration of the models into lesson	Knowledge and skills about how to use the STEM approach in teaching mechanical energy conversion are informed.
6th	STEM Pneumatic workshop (Folding door design) Integration of the models into lesson	Knowledge and skills about how to use the STEM approach in teaching pressure are informed.
7th	STEM Optic workshop Integration of the models into lesson	Knowledge and skills about how to use the STEM approach in teaching optics are informed.
8th	Original Engineering Design Model Integration of the Models into lesson	An original model is designed by following the EDP steps is informed.
9th	Design the Model Promotion Booth STEM Model Exhibition	Knowledge and skills are gained about the promotional booth of the model. The original model is put on display.

In the research, 40 science teachers (20 of 40 teachers participated in the first workshop period and the other 20 of 40 teachers participated in the second workshop period) were selected as participants. The sample group was formed by using the criterion sampling method, one of the purposeful sampling methods. These teachers' project proposals were accepted within the scope of the TUBITAK Science Fair in 2015 or during previous years. They participated in the workshop on a voluntary basis. The demographics of the participants were given in the table below.

Table 1

Demographic Variables of the Participants

Variables		f
Gender	Female	17
	Male	23
Seniority	0-5	13
	6-10	12
	11-15	7
	16-20	6
	21-	2
School setting	Rural	18
	Urban	22

Data collection and analysis

As a data collection instrument, a scale was developed by researchers: The Questionnaire for Interdisciplinary Association of Science (QIAS). The instrument aims at determining the effectiveness of the workshop on how science teachers recognize the relationship between science and other disciplines. The questionnaire consisted of two parts; Part A - Demographic Information Form, Part B - Interdisciplinary Relationship Perception Test. In Part B, there is a main question structured as "What disciplines do you think science is related to?" and there are 5 lines structured as "Science is related to ………………………. because …………………………" following the main question. In this part, teachers are expected to write the disciplines they think are related to science and explain the interdisciplinary association is between them.

The QIAS was given to the participants before (Part A and Part B) and after (Part B) workshop sessions. The forms were then analyzed with content analysis. Besides the teachers' ability to associate science with other disciplines, it was also the aim of this research to determine the extent to which they could prove it in their classes. For this purpose, the lesson plans were prepared by the participant teachers at the end of the workshop and were examined. Before performing content analysis on the lesson plans, two main criteria were set by reviewing the relevant literature (Guzey et al., 2016; Kier et al., 2013; Siverling et al., 2017): (1) What discipline(s) cover(s) the acquirements or topics which were found pertinent to the acquirements in the lesson plans? (2) What teaching philosophy/philosophies (disciplinary/interdisciplinary) and teaching methods in the lesson plans is/are? Then, the lesson plans were analyzed, and the findings were displayed via tables and graphs.

Furthermore, semi-structured interviews were held with the teachers about their lesson plans which were the outcomes of the workshop. The interviews were voice-recorded and transcribed for content analysis. In addition, since the interview data were primarily used to describe the present situation, direct quotations were included to better represent the participants' perspectives and to make the depicted situation more vivid in the reader's mind. Lastly, the interviewees were coded as K1, K2, …., K40 for confidentiality.

In this research, the researchers used data triangulation to analyze the three different data collection tools. Yin (2014) described data triangulation as a convergence of numerous sources of data to create an in-depth, real-world understanding of the case study. Data triangulation strengthened construct validity (Yin, 2014). To increase construct validity, a draft research report was reviewed by another peer (who has experience in case study research) and 3 informants. The peer and 3 informants were asked to examine the draft paper then made the necessary corrections and the research paper has taken its final form. To ensure reliability and minimize the possible bias, all kinds of data (QIAS, lesson plans, and transcribe of interviews) were coded by researchers independently to find themes focusing in the research questions and then were coded the data independently and then compared with each other.

Findings

Findings on the Effect of the STEM Workshop on Science Teachers' Awareness about the Relationship between Science and Other Disciplines

This part of the paper was dedicated to findings concerning the first aim of the research. As the first part of the data collection procedure, the QIAS was applied as a pre-test and post-test in order to reveal which disciplines were thought to be associated with science by the participants. The respondents filled out the questionnaire forms by identifying five different disciplines that they perceived connected to science and explained the direction of the connection. The pre-test and post-test were completed by 40 teachers. The frequencies of the disciplines were tabulated with corresponding explanations, respectively. The responses were shown in Table 3.

Table 2

The Disciplines Reported by Teachers in Connection with Science Before and After the Workshop

Related disciplines	f		The direction of the related disciplines	
	Pre	Post	Pre-test	Post-test
Math	34	38	(1) Includes analytical thinking and analysis (2) Requires the ability to make mathematical operations (3) Includes obtaining, calculating, and interpreting the necessary data	(1) Shared processes of data collection and analysis (2) Maths; the language of expressing sciences (3) Making calculations while planning and modeling (4) Using similar calculations in different learning units and subjects (5) Connection between concepts based on numerical data (6) Helping find technical errors
Technology-design	27	35	(1) The practical step of science (2) Advances in technology and science affect each other (3) Requires a broad imagination (4) Puts out a product	(1) Covering the working principles and designs of gadgets (2) Keeping up with developments, being open to innovations, and being up to date (3) Obtaining new products by integrating knowledge into technology (4) Producing technological products with an understanding of science and by observing nature (5) The role of design in associating science topics with real-life (6) Using scientific knowledge and requiring the generation of different ideas

Visual arts	11	11	(1) Imagining and drawing (2) Learning by sight ensures permanence of learning (3) Material development and retention of visual expression (4) Concretising of concepts	(1) Similarity in the design process and planning stage (2) Presentation of the model, demonstrating its closeness to reality (3) Design and putting out a product (4) Drawing and dimensioning skills
Social studies	9	8	(1) Similarity of subject contents (2) Contains historical and environmental elements (3) Making progress by following the changes from past to present	(1) Solving social problems (2) Benefitting from social sciences in developing useful products for the country-society (3) Similarity of subject contents (4) Teaching skills such as sharing, teamwork, communication, etc.
Engineering	8	29	(1) Emergence of engineering studies through the principles of science (2) Includes daily life applications of science	(1) Putting out a new product by combining various scientific rules while modeling (2) Using the principles of science in engineering (3) Teaching the ability to integrate materials in different ways (4) Design and application process (5) Using scientific approaches in engineering designs (6) Modelling of the ideas designed (7) Continuous support exchange among different disciplines
Music	6	3	(1) Similarity of subject contents (2) Learning by hearing supports permanence of learning	(1) Similarity of subject contents
Turkish language	5	9	(1) Sense-making and perception process (2) Reading comprehension and interpretation (3) Ability to express oneself	(1) Expressing oneself, understanding what one reads (2) Teaching skills such as reading, understanding, interpreting, etc.
Physics	5	8	(1) Understanding and explaining nature events (2) Sub-discipline	(1) Concretising of concepts (2) Necessity to know the rules of physics in a new design (3) Associating with real-life (4) Explaining the laws of nature
Chemistry	5	5	(1) Sub-discipline (2) Understanding that matter relationships are important for understanding the universe	(1) Explaining the laws of nature
Biology	5	3	(1) Sub-discipline (2) The relationships among living things are examined	(1) Explaining the laws of nature
Others	22	21		
Total	140	170		

As Table 3 shows, in the pre-test, 34 of 40 teachers associated the science lessons with mathematics, and in the post-test 38 teachers associated the science lesson with mathematics. So, the subject most associated with science lessons was mathematics both before and after the workshop. In the pre-test, knowledge of mathematics was determined to attract much attention due to certain requirements of the science lesson such as formula-based calculations, drawing and interpreting charts, converting different units. In the post-test, the most emphasis was placed on "using similar calculations" in both disciplines. Teachers pointed that numerical data play a crucial role in revealing relationships between concepts and certain calculations, and the processes of collecting data and analysis are shared in interpreting concepts.

Another lesson associated with science was the process of technology-design. In the pre-test, 27 of 40 teachers associated the science lessons with the process of technology-design, and in the post-test 35 teachers associated with it. Before the application, the teachers explained this relationship by stating that both disciplines are parts of the practical stage of science requiring a wide imagination and constructing a product. As for the post-application, science was associated with technology-design in a particular relation with designing a product and constructing a product. In addition, they pointed out that both these disciplines require keeping up with developments, being open to innovations, and being up to date. Moreover, they supported each other in relation to everyday life, and they necessitated using scientific knowledge, generating knowledge, and putting forward new ideas through similar processes.

Science was associated with engineering, too. In the pre-test, only 8 of 40 teachers associated the science lessons with engineering, and in the post-test 29 teachers associated with it. There was a significant increase in association from the pre to post-application. It was seen that the participants referred to science-related studies and accumulated knowledge as the basis of engineering in the pre-test. They added that these two fields continuously exchange support leading to the rising of new knowledge and technologies and engineering allows using science in everyday life. After the application, the direction of this interdisciplinary relationship was explained with aspects common in design and implementation. The two fields were found to be directly connected in that engineering processes are used in the science lessons, ideas are modeled, designs are made, and products were put out. Similarly, direct reference was made to science-related knowledge in generating engineering products. In short, the teachers associated science and engineering in the dimensions of the knowledge used and the practical stages.

As another associated discipline, the Turkish language was referred to with the same opinions in the pre and post-test. Likewise, science was associated with the Turkish language in terms of understanding and interpreting what one reads and expressing oneself. It was underlined that these skills are very important in both disciplines.

Another interdisciplinary relation was made between science and social studies with similar propositions in the pre and post-test. The teachers stated that similar contents are covered in these disciplines (e.g. formation of the Earth, the planets, fossils, energy sources…), so scientific advances cannot be independent of social needs, and science was utilized for solving social problems.

When the participants' responses for the relationship between science, physics, chemistry, and biology disciplines are examined in the pre-test, participants stated that these disciplines are already within the scope of science and that science cannot be considered as independent of them. However, in the post-test, emphasis was placed on the source of knowledge in associating science with physics, chemistry, and biology. Also, observing nature, revealing/explaining the rules of nature to build bridges between subjects/topics, and accumulation of knowledge were indicated in that test as well.

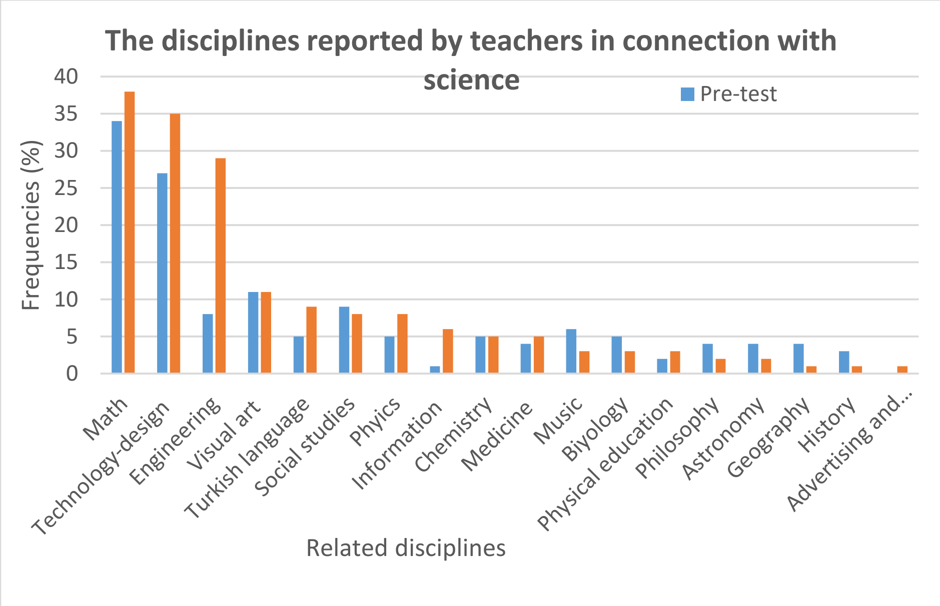
In addition, an association was found between science and visual arts by indicating to use of the latter as an instrument for the concretization of concepts, drawing of dreams, and developing applicable materials in order to ensure permanence of learning at the pre-test stage. After the implementation, it was found out that these disciplines had in common in the design process and planning stages, drawing skills, requiring dimensioning skills, design, and constructing a product.

Lastly, an association was noted among science and medicine, physical education, astronomy, music, and environmental sciences. Again, similar contents were underlined before the application in the research. However, after the application, reference was made to physical education in that practical outcomes of this discipline can be utilized in topics like force and movement. In the same manner, a relationship was elicited between science and music by means of similar contents. The participants mentioned that the topic of sound in the curriculum of science for various grade levels has a connection with the contents of the music course.

In summary; other disciplines considered associated with science demonstrated that there was clustering around certain disciplines both before and after the workshop. But, frequencies of lessons associated with science increased from pre (f=140) to post (f=170) application. The direction of the relationship was explained in more detail in post-application. Fig. 1 shows shifts in interdisciplinary relations from the teachers' perspective at the beginning and end of the STEM workshop.

Figure 1

Shifts in Interdisciplinary Relations from the Teachers' Perspective at the Beginning and End of the STEM Workshop



As seen in Figure, 1, although there appeared a sharp difference in interdisciplinary relations such as engineering (8-29), technology-design (27-35), and information technologies (1-5) after the workshop, not many shifts were seen in a variety of the disciplines associated with science from the pre to post-test. In other words, most relations were drawn with almost the same disciplines in both tests. But there was one fact worth noting that the teachers could provide extensive and exhaustive explanations regarding the direction of the relations in the post-test.

Results on the Effect of the STEM Workshop on Science Teachers in Transferring the Interdisciplinary Relationship to Lesson Plans

In the previous part, it was noted that the participant teachers associated science with a wide range of other disciplines. In this part, findings were given regarding the second aim of the research: to reveal to what extent and in what way science teachers could relate such association to their teaching practices. For this purpose, the teachers' resulting lesson plans were analyzed and interviews were held with the teachers to confirm the findings.

The results of the analysis of the lesson plans are presented in the main lines in Table 4. They are reinforced with other visual representations particularly about "the teaching philosophy/philosophies (disciplinary/interdisciplinary) and teaching methods in the lesson plans (see in Fig. 2)", "the frequency of associating the science lesson with other lessons (see in Fig. 3)", "the disciplines associated with the science lesson (see in Fig. 4)", and "the topics covered under other disciplines associated with the science lesson (see in Table 5)". Finally, the findings obtained from the unstructured interviews with the teachers were given below to depict their status in putting the interdisciplinary approach into practice.

Table 3

Linking the Science Topics in the Lesson Plans with Topics in Other Disciplines

Disciplines		Topics
Science		(1) Heat Insulation, (2) Sound Insulation: Designs Padded Media, (3) Domestic Solid Wastes: Projects on Recycling of Solid Wastes, (4) Designs Musical Instruments, (5) Makes the Liquid Waste Conversion Model, (6) Phase of The Moon, (7) Convex Lens – Realizes That Glass Wastes in Forests Can Cause Fire, (8) Reflection of Light Making A Periscope, Designs an Imaging Tool By Using Mirror, (9) Light Pollution, (10) Light Transmissivity of Matter, (11) Let's Recognise Our Plane, (12) Night and Day Event, (13) Sense Organs: Emphasises Technologies That Facilitate the Hearing-Impairer's Life, (14) Visual Health, (15) Electrical Circuit Design, (16) Food Protection, (17) Measuring Force: Designs A Simple Dynamometer, Air and Water Resistance, (18) A Unique Lighting Tool, (19) Precaution Against Acid Rain, (20) Simple Machines, (21) Environmental Problem-Stream Pollution, (22) Environmental Problems-Waste Batteries, (23) Using Resources Sparingly
Other Related Disciplines	Technology	(1) Designs According to The Properties of Materials. Searches The Internet for Information and Uses It on SmartBoard. (2) Develops Tools That Make Life Easier. (3) Examines Technological Tools for The Hearing-Impaired and Develops Unhindered Life Technologies. (4) Follows the Developments Around Them, Develops an Original Design. (5) Gives Examples of Daily Life and Uses in Technology. Researches Visual and Verbal Presentation Techniques and Presents the Product. Designs Original Materials. (6) Searches The Internet for Information. (7) Searches The Internet for Information on Acid Rain, Solves the Problem Using the Information Obtained, Makes an Original Design. (8) Searches The Internet for Information on Insulation Materials. (9) Realizes the Contribution of Recycling Facilities to the Economy. (10) Researches Optical Technology on the Internet; Develops Visual Communication Design and Unhindered Life Technologies. (11) Solves the Problem Encountered in Daily Life by Using Knowledge. (12) Using Binoculars, Examining the Development of Binoculars. (13) Searches The Internet for Information on Building A Periscope.
	Social Studies	(1) The Crusades on The Ottoman, Values Education, Commitment to The Past, Patriotism, Citizenship Awareness. (2) Behaves as A Conscious Consumer. (3) Being Sparing as a Conscious Citizen; Protects Natural Resources and Has Understanding of a Sustainable Environment. (4) Citizenship Tasks and Efficient Use of Natural Resources. (5) Connects the Institutions Concerned to Meet the Social Needs. (6) Conscious Use of Natural Resources and Being Sparing. (7) Evaluates the Effects of Developments in Technology on Life. (8) Gives Social Message with the Musical Instruments They Developed. (9) Protects and Cares about Their Immediate Environment; Protects Natural Resources Within the Scope of Environmental Awareness and to Have a Sustainable Environmental Understanding. (10) Puts Oneself in the Place of a Visually Impaired Person (11) Realizes the Effect of Scientific Events on Life: The Tidal Event. (12) Values Education-Recognising the Environment in Which They Live, Keeping It Clean, Protecting and Caring about It.
	Engineering	(1) Constructs the Model by Using Suitable Materials. (2) Designs a Model to Classify Matters According to Their Electrical Conduction. (3) Designs a Simple Dynamometer. (4) Designs and Develops a Simple Ramp. (5) Designs Models Using EDP Steps. (5) Designs the Model Showing the Phases of The Moon. (6) Develops a Model by Applying the EDP Steps with Materials Around. (7) Develops Food Storage Container. (8) Draws, Designs, and Develops a Lamp for the Problem. (9) Uses EDP Steps Consciously.
	Mathematics	(1) Angle Measurement, Dimension Measurement, Calculation, Creates the Pythagorean Relation, Solves Related Problems, Relation Creation. (2) Algebraic Operations, Analysis of Data. (3) Calculates Cost, Makes Area Measurement. (4) Calculates the Time Elapsed Between Phases. (5) Calculates, Creates, and Reads Graphs, Collects Data. (6) Calculation, Geometry, Recognises Units of Area Measurement. (7) Measures and Records the Amount of Light in the Environment, Draws a Graph.
	Visual Arts	(1) Draws and Presents the Design of the House with Heat Insulation. (2) Draws a Two-Dimensional Picture of The Model. (3) Draws the Waste Model and Presents It to The Class. (4) Makes a Poster About Acid Rain. (5) Makes the Sketch Drawing of The Model. (6) Sketches the Model to Reduce Light Pollution and Presents It to the Class. (7) Draws and Presents a Unique Lamp.
	Turkish language	(1) Essay Writing
	Medicine	(1) Ear Health.
	Music	(1) Taps Out the Rhythm of Something.
	Biology	(1) Realizes the Effect of Wastes on Living Things in the Stream.

As can be also seen from Table 4, science subjects were related to other subjects or topics in 37 of the lesson plans prepared by 40 participants. Only 3 teachers did not prepare lesson plans in connection with other disciplines.

Apart from this, an analysis was performed to find out the teaching philosophy guiding the integration of other disciplines into science. As a result, the teaching philosophies and teaching methods inspiring the lesson plans were given in Fig. 2.

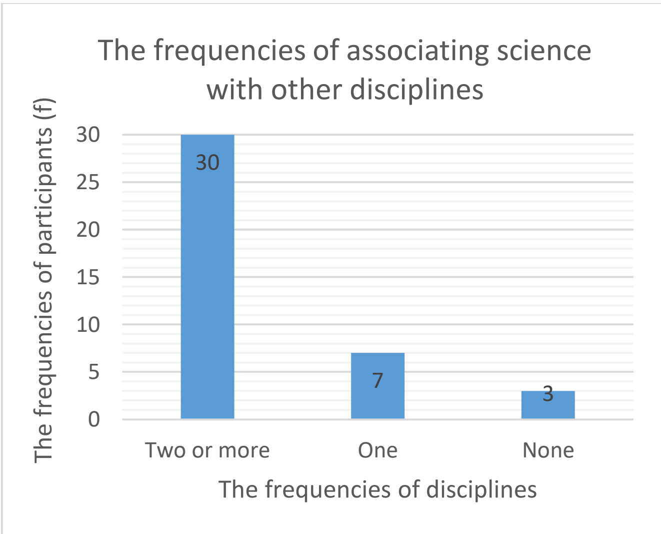
Figure 2

The Teaching Philosophies and Teaching Methods Adopted in the Lesson Plans

As can be seen in Fig. 2, most of the teachers created their lesson plans around an interdisciplinary approach and predominantly used the EDP method as the teaching method in order to create the learning environment. On the other hand, only a few of them developed their lesson plans based on a disciplinary approach preferred the presentation method and 5E learning cycle for teaching. As another finding, the frequency of associating science with other disciplines is the 37 lesson plans shown in Fig. 3.

Figure 3

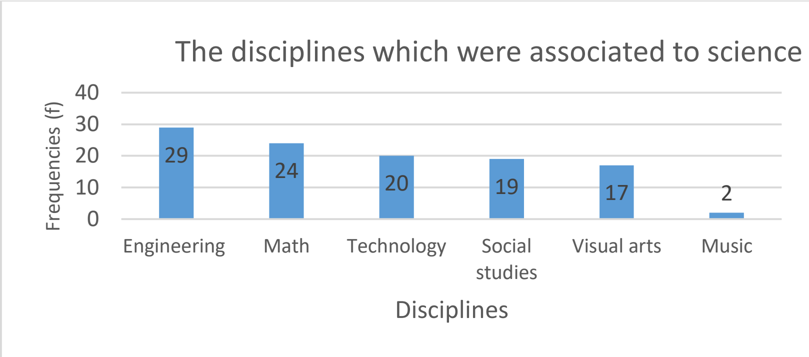
The Frequencies of Associating Science with Other Disciplines



According to Fig. 3, most of the teachers could associate science with two or more disciplines, while very few of them referred to one single discipline. Fig. 4 shows the associated disciplines with science in teachers' lesson plans.

Figure 4

The Disciplines Which Were Associated with the Science from the Teachers' Lesson Plans



Teachers' lesson plans examined, it was revealed that they mostly associated engineering and mathematics disciplines with science-related subjects. This order was followed by technology, social studies, and visual arts. The disciplines which received the least reference were noted as biology, medicine, and music. When a glance is taken at the topics of other disciplines dealt in relation to the science topics in the lesson plans, the following findings were reached.

Table 4

Topics under Other Disciplines Associated with the Science Lesson

Other Disciplines	Topics	f
Mathematics (55)	Makes four operations	12
	Collects and analyses data	7
	Makes measurement	6
	Has knowledge about angles	5
	Makes algebraic operations	4
	Analyses	3
	Solves problems	3
	Draws and reads graphics	3
	Recognizes measurement units	3
	Indicates by symbol	3
	Draws an angle congruent to another	2
	Creates the relation	2
	Make operations with decimal numbers	2
Engineering (40)	Uses the EDP steps	6
	Develops a model	6
	Makes problem-oriented design	5
	Creates a three-dimensional model	5
	Obtains material knowledge	5
	Designs models	4
	Understands the problem, hypotheses, draws, creates, develops	3
	Designs and makes a model	2
	Designs and creates	2
	Searches	2
Technology (32)	Searches the Internet for information.	7
	Solves the problem encountered by using knowledge.	5
	Examines technological tools.	4
	Draws and presents the design.	3
	Examines the effect on daily life.	3
	Develops tools to make life easier.	3
	Develops unhindered life technologies.	3
	Searches visual and verbal presentation techniques.	2
	Develops an original design.	2

Social Studies (30)	Values education.	7
	Conservation of natural resources.	6
	Conscious use of natural resources.	5
	Being sparing.	2
	Citizenship awareness.	2
	Puts oneself in the place of disabled individuals.	2
	Behaves as a conscious consumer.	2
	Realizes the effect of scientific events on life.	2
	Recognizes social organizations.	1
	Evaluates the effects of technological developments on life.	1
Visual Arts (17)	Makes and presents the two-dimensional drawing of the model.	15
	Makes a poster.	1
	Draws the two-dimensional sketch of a 3D model.	1
Music (2)	Gives a social message with the musical instruments they developed.	1
	Taps out the rhythm of something.	1
Medicine (1)	Ear health	1
Biology (1)	Realizes the effect of wastes on living things in the stream.	1

According to Table 5, the leading subjects integrated into science lesson plans were mathematics, engineering, technology, social studies, and visual arts subjects, respectively. As the top item, mathematics was referred to as using mathematical skills such as calculating science topics, collecting and recording data, making a measurement, using knowledge about angles, and performing algebraic operations. Secondly, science was related to engineering with respect to practicing engineering such as using the EDP steps, developing a model, designing for the problem, creating a 3D model, obtaining knowledge about materials, and designing models. Thirdly, technology was integrated into science teaching as to looking for information on the Internet, solving the problem faced by using the knowledge, and examining technological tools. Another discipline, social studies were seen to be referred to as values education, conservation of natural resources, and conscious use of natural resources. Lastly, visual arts were involved in the lesson plans as it was offered to make a 2D drawing of a model and present it to the class. Apart from the disciplines above, the science teachers supported their plans with music, medicine, and biology with topics under each of these disciplines too superficial to note.

As a result of the interviews, it was seen that majority of the participants stated that it would be more appropriate to use more than one discipline in one place depending on the content of the subject rather than integrating one certain discipline.

"In fact, most of the topics in maths lessons can be taught in science classes… What is learned in maths lessons is used for solutions in science lessons. While teaching the day and night events in my science lesson plan, it can be reinforced with social studies lessons under geography. Students in the classroom learning through this lesson plan can design a model showing the day and night event by using engineering design (K6)."

The participant, K15, suggested that multidisciplinary learning of any science topic can make learning more permanent.

"For example, mathematical formulas are needed to tell the distances between the earth, sun, and moon, making the calculations while teaching this topic. I can explain the satellites sent to other celestial bodies through engineering studies. I can talk about how technological tools are made. The names of the organizations that do all these things are in foreign languages, the names of celestial bodies: stars, spacecraft… language is needed to understand them. The position of our world falls into the area of geography, or discoveries are the work of geographers. I will mention it… At the end of the lesson, I can make them write an essay about the journey to the moon (K15)."

When the associations by specific disciplines were evaluated, those concerning maths were observed to be prominent in teachers' interviews. In this framework, the teachers stated that mathematics is applied in transactions such as mathematical calculations, interpretation of graphs, and conversion of different units as a part of science lessons. They added that students need to possess mathematical operation skills since they can learn more permanently in this way.

> *"I would like them to design and build dynamometers with simple materials ... In the course of teaching; I will bring mathematical information to the foreground while teaching a formula between elongation and mass. Once they have the right mathematical knowledge, I will ensure permanence of the formula (K17)."*

Following maths, science was the most associated with engineering. Particularly, the interviewees stated that the engineering discipline can be integrated into science in the form of using the engineering design stages, knowing these stages and producing solutions and models by using these stages, especially in the solution of daily life problems related to the topic in question in the science lesson.

> *"In my lesson plan, I will ask my students to perform experimental setting design, model construction in connection with engineering and design. To give an example, I would ask them to design an insulated house or box model for the problem which involves a piece of ice that stays without melting for a long time. In this model, calculation, design, and how engineering topics are used to be described step by step. At the end of the class, melting, heating, radioactive heat transfer, heat insulation, model design, model building stages are elicited (K1)."*

It was also found out that science lesson was associated with technology and design lesson. Particularly, reference was made to the latter in concretizing the abstract concepts in the science curriculum, encouraging students to design models relying on their imagination and creativity, and ending up with a concrete product.

> *"They can make a simple periscope model by using the technology related to making periscopes, looking for information on the Internet, and developing possible solutions to the problem situation, making visual arts and drawings. As for maths, they can calculate the angle of rays. A periscope is made in simple materials by using EDP design steps and then presented in the classroom corridor...(K19)"*
>
> *"In my lesson plan for domestic waste, we can relate to technology and design course and visual arts course. To develop a solid waste facility, I can ask students to use the Internet technology to collect information, to use their visual arts knowledge by drawing while they are creating a model, and to use their knowledge from technology and design lessons in the designing stage... also, they can use the maths knowledge while buying cartons and other materials by calculating the area for constructing the model and calculating the money in the material purchase (K31)."*

Regarding the teachers' connections between science and social studies lessons, some quotes can be seen below:

> *"…Using resources sparingly cover the efficient use of energy resources and environmental pollution in the social studies course. In the plan, students are expected to design a model or method to save electricity power... for this, I will ask them to use EDP steps and work like an engineer… (K21)"*
>
> *"…Waste batteries are a problem that our students face every day because there is no waste battery box in our school. I will tell them to save batteries without polluting the soil and water as a conscious citizen... I would expect the students in the classroom where I will apply my plan to look for information on the Internet and design and present a battery-saving box... I would also expect them to draw a two-dimensional model using their design skills in visual arts lesson… (K6)"*

In relation to visual arts, the participants reported applying this discipline for various purposes at various stages of their classes. It was concluded from their responses that students' drawings facilitate learning, and thus making learning permanent in the particular context of a concretization in certain topics of science.

> *"I will use visual arts in teaching abstract subjects or concrete subjects in science class. In this lesson plan of mine…. makes the model sketch to make a sound-insulated box... I think using visual materials or my own drawings in order to ensure the permanence of students' learning*

reinforces the learning… After maintaining permanent learning of the student, I would ask them to design a visual material to show the sound-insulated box in question... (K11)"

"Science is intertwined with painting because the child depicts what he sees, sometimes he draws a model. It is very important that they build a simple electrical circuit by themselves and draws what they use.… They design and present a model to classify materials according to their electrical conduction by using the electrical circuit designed by using engineering knowledge…(K30)"

One other participant indicated an association between science and visual arts by defending that drawing makes classes funny, making learning easier.

"I love having them draw pictures, write and sing songs, write stories and act drama about the topic I teach in my classes… students will develop a musical instrument using the materials around by following the EDP steps and we can sing a song together by tapping out the rhythm… Take a song that gives social messages, and there are many such songs on the Internet…(K8)"

Another discipline with which science was associated was music. The participants stated that they integrated this discipline into the relevant science unit especially owing to the fact that the topic of sound is covered at different grade levels in the science curriculum.

"I believe that when the 8th-grade students design a musical instrument using the design loop or try to do it, they will understand the features like high pith and deep voice and learn better… (K3)"

"…at the beginning of the class, I can ask the music teacher to bring any musical instrument to the classroom and play it in the unit of sound and draw the students' attention to the vibration in the water on the table... I will ask them to make a musical instrument that will vibrate this glass more so that the children can see the high pitch-frequency relationship for more memorable learning (K5)."

Conclusion, Discussion and Implications

In this research, it was attempted to shed light on the role of the tailored STEM workshop on science teachers' gaining an interdisciplinary understanding and applying this understanding to their lesson plans. To this end, data collected through the QIAS survey, lesson plans, and interviews were analyzed.

When we look at the range of disciplines the science teachers associated with science, it can be seen that the diversity of the disciplines did not differ a lot between the pre-test and post-test, suggesting a large number of references to mathematics, technology-design, social studies, engineering, visual arts, Turkish language, and music. Nonetheless, the teachers could provide more elaborative and satisfactory explanations regarding the direction of the interdisciplinary connection at the post-test (see Table 3). Additionally, the same test yielded a marked change in favor of engineering, technology-design, and information technologies (see Fig. 1).

When the rising of awareness regarding the relationship between science and other disciplines was examined in-depth, mathematics stands as the most frequently mentioned discipline connected with science before the workshop (Cinar et al., 2016a; Cinar et al., 2016b; Eroglu & Bektas, 2016; Kizilay, 2018). Similarly, other researches on interdisciplinary approaches reported mathematics as the prominent discipline associated with science. It could be owing to the fact that the tie of mathematics with real life is the most evident when science is in question (Cantrell et al., 2006). The awareness of the teachers in our research was maintained and even showed an increase after the workshop (see Table 3). The participants explained that numerical data are quite important in revealing the relationships between the concepts and interpreting the concepts in both disciplines and that similar calculations and processes are used in data collection and analysis processes. The slight increase of awareness in the post-test can be accounted for by the combined use of scientific and mathematical concepts during engineering design activities. In the workshop, the teachers used scales, rulers, and protractors to measure, collect, record, and analyze data such as mass, length, area, and slope. They obtained results and formulas as a result. For example, in the amusement park high-speed train design activity, science teachers made calculations, collected data, and made up a Formula ($h = R / 2$) to reveal the relationship between the height of the starting point of the rail system and the radius of the rail circle for safe rotation from the circles in the rail system. Evidence was found in not only workshops but also lesson plans that the training helped the participants better understand the relationship between science and mathematics. Analysis of the teachers' lesson plans demonstrated that mathematics was the most popular supplementary subject (see Fig. 3). Regarding the mathematical topics incorporated into science, there was a blended use of mathematical skills such as calculating, collecting, and recording data, measuring, applying knowledge of angle, and performing algebraic operations. As the other pillar, the interviews regarding lesson plans revealed that science teachers appealed to mathematics in particular connection with mathematical calculations, interpretation of graphs, and conversion of units. They suggested that students should be able to make mathematical operations so that learning can be more permanent. As an example, a teacher (K17) mentioned their lesson plan as follows: "I would like them to design and build dynamometers with simple materials ... in the lesson; I will bring mathematical information to the foreground while teaching formulaic information between elongation amount and mass. Once they have the right mathematical information, I will ensure permanence of the formula…" This statement supports our argument above.

As another interdisciplinary suggestion, technology and engineering were seen to be associated with science at quite a lower level compared to mathematics during the pre-test (see Table 3). The teachers' statements "Emergence of engineering works thanks to science principles" and "Containing everyday uses of science" imply that they were not fully aware of this relationship. Marulcu and Sungur (2012) also noted that prospective science teachers regarded engineering as a synonym of constructing and building and related engineering designs to the trial and error process. Dugger (2010) explains this finding by arguing that science and maths among STEM lessons were ignored, and only little emphasis was placed on these disciplines. Other reasons could be two-fold. First, the teachers had very limited experience in interdisciplinary learning when they were in secondary education years. Second, they might have received undergraduate education which placed inadequate emphasis on the interdisciplinary approach that would contribute to the development of pedagogical content knowledge along with the subject field knowledge (Cinar et al., 2016b). Bybee (2010) stated it would not be sensible to expect individuals to draw a proper relation among STEM disciplines after going through STEM classes which place only little weight on technology and engineering. Interestingly enough, the participants in our research recorded a significant increase in awareness regarding the relationship between science and technology and engineering after the workshop (see Fig. 1). They thought that engineering and science are in a direct relationship as design processes take place in science lessons, ideas are modeled, and products are given as a result of design. Similarly, they pointed out that scientific knowledge is appealed in putting out engineering products. In support of this situation, Apedoe et al. (2008) stated that teachers involved in EDP activities were successful in engineering concept teaching and had increased awareness about engineering as a discipline. After the training, the direction of this relation was seen to mostly specify processes of design and implementation. The Report of the Standards for Technological Literacy (2007) underlines that EDP is a critical method in teaching technology and engineering concepts. Thanks to this method, individuals can learn the concepts and principles related to the design and design process as a part of problem-solving (Avary, 2013). This could be due to the fact that STEM disciplines were integrated into the science lesson in particular connection with engineering design problems during our workshop. For instance, in the STEM statics workshop, the participants were instructed to construct a long, cheap, durable, and aesthetic bridge from the materials at hand in the Savur district of Mardin, where Nobel-winning Aziz SANCAR was born and grew up. The teachers made several different bridge models and tested their strength by putting weight on the bridges and thus developed the most suitable bridge. According to researchers (Brophy et al., 2008; Thornburg, 2009), EDP, which corresponds to the productive phase of technology, naturally relates STEM disciplines with each other since it requires the use of basic engineering knowledge and skills and the principles of science and maths. The analysis of the lesson plans also revealed that science was tied with engineering and technology at the highest level. The proof was available in some of the lesson plans blending science with topics of engineering such as using EDP steps, developing models, designing for problem-solving and models, creating a 3D model, and obtaining knowledge about materials. As for the topics concerning technology, they were listed as looking for information on the Internet, solving the problem faced by using the existing knowledge and examining technological tools. In the interviews, the teachers told that the engineering discipline can feed science in terms of using engineering design stages for solving daily life problems connected with science, having knowledge of such stages, and proposing solutions and models by means of these stages. For example, participant K14 stated "In my lesson plan about the original design, I would like to ask them to identify one of the main problems in their daily lives and propose more than one solution to the problem, make design drawing of the best solution proposal, create models and products suitable for their design. During their design process and making the product, I will make them brainstorm about how much they changed the design to make up deficiencies. I will give questions to them such as the function of their project in the technological field or what it will make easier. Finally, I would ask them to present the construction stages of this project, its objective, whom it addresses to, and what facilities it provides". This change in the teachers' attitude could be caused by design works in the statics workshop covering stages such as identifying the problem, ghost phase, planning, and devising, and producing stage, mechanics workshop, and original design workshop which boosted the teachers' interests and motivations about engineering (Ercan & Sahin, 2014; Roth, 2001; Tal et al. 2006; Wendell et al., 2010).

In addition, science teachers did not only associate science with STEM disciplines before and after the workshop but also with other disciplines such as social studies and visual arts (Eroglu & Bektas, 2016). When attention was paid to the workshop's triggering the teachers' realization of the relation between social studies and visual arts, no significant difference was found between pre and post-test scores of the QIAS (see Table 3). However, the lesson plans showed that most teachers included social studies and visual arts topics in their science plans (see Fig. 3). These subjects were involved in a particular context of "values education", "conservation of natural resources", and "using natural resources consciously". As for the topics of visual arts, "making 2D drawings and presenting" was mentioned. It can be suggested that our workshop had a catalytic impact on science teachers in acknowledging the relation of science with social studies and visual arts. It could be substantially owing to the fact that the teachers proposed solutions to life-related problems as a result of the engineering design activities (Silk et al., 2009; Wendell, 2008). In this regard, the teachers handled some life problems like "designing a crazy amusement park with a high-speed train can be seen from all over the city", "designing a folding door for a shopping mall", "designing a communication system on a deserted island", "designing a safe pedestrian crossing", and "designing a unique system for tea collection or transport". They completed several tasks such as proposing many solutions based on EDP, choosing the best solution, making 2D drawings of them, and presenting their products to the class. Apart from the foregoing, other disciplines such as music, medicine, and biology were also annotated in science lesson plans. According to Wendell (2008), the teaching of classes by using everyday life problems encourages students to produce more than one solution to the problem and to bring other disciplines into the solution processes. In support of this, Niess (2005) argues that teaching blending multiple disciplines will provide learners with information about other disciplines at the same time.

As can be seen, science teachers who participated in the workshop made connotations with many different disciplines in relation to science. For the second aim of the research, it was analyzed how and to what extent the teachers could benefit from this connotation in the teaching of science. In the lesson plans, STEM-based activities were heavily related to physics, particularly for teaching heat, sound, optics, and simple machines (Siverling et al., 2017). But other sub-branches of science such as chemistry, biology, and environment were not dealt with much in the lesson plans. In parallel with our finding above, Eroglu and Bektas (2016) concluded that science teachers planned teaching of

STEM-based activities by referring to topics under physics. Considering that not only physics subjects are included in the science curriculum, this result seems to be a disappointing thing for the course. This may have been due to the fact that the STEM design workshops held throughout the course included areas of physics including statics, mechanics, pneumatics, and optics. A review of the literature shows studies carrying out STEM activities in other areas of science (Ellefson et al., 2008; Kolodner et al., 2003; Mooney & Laubach, 2002; Siverling et al., 2017). It can be said that our workshop was one-sided leaving out other areas of science. It is thus recommended to expand future STEM workshops for teachers to include STEM activities concerning other fields of science like chemistry, biology, environment, and astronomy.

Zooming in the way science teachers could explain science with supplementary discipline(s) in their lesson plans indicated the existence of an interdisciplinary approach. As for the corresponding teaching method, most of them with the interdisciplinary understanding used the EDP, which is the method relying on design, whereas the rest applied the 5E learning cycle, project-based learning, and problem-based teaching methods. Again, few of them were seen to plan their lessons around a disciplinary approach and use presentation and 5E learning cycle as teaching methods (see Fig. 2). Sandall et al. (2018) conducted a study with teachers specializing in STEM fields and the majority of the respondents stated that STEM education should be performed by means of design-based and project-based teaching methods. This could be a direct effect of the activity titled "How to Integrate the Models into Lesson" describing how to use the design models developed as a result of the STEM workshops in classes. Recalling that the STEM activities in the 2018 Science curriculum were proposed in a design-based approach, the workshop developed here can be said to contribute to the field considerably. Yet, the literature shows that other methods were also utilized in preparing STEM activities (Asik et al., 2017; Stohlmann et al., 2012). On the other hand, the workshop briefly covered methods of STEM education including the 5E learning cycle, project-based learning, and problem-based learning, and implemented a specific activity about developing lesson plans accordingly. It must be added that the STEM workshops were completed with activities based on the engineering design method. This may have convinced the majority of the teachers to make lesson plans based on the engineering design method, which seems to be a deficiency of the STEM workshop developed here. Hence, the need arises to arrange activities for project-based learning, problem-based learning, 5E learning cycle, and inquiry-based learning in future STEM workshops.

All in all, it was understood that the education given to science teachers in the field of STEM had favorable effects. This looks promising for Turkey in terms of STEM training based on engineering design because science teachers managed to bridge science and many other disciplines. To put in another way, teachers in this research achieved one of the main objectives of STEM and the MoNE's science curriculum in 2018 at the same time. Further studies are available in the literature which argue that STEM education improves teachers' understanding (Lambert et al., 2018; Siew et al., 2015). Thus, it can be suggested that such training will enlighten teachers about STEM so that they can implement STEM activities more effectively in the classroom. Therefore, the number of such training on STEM should be increased, and this workshop should be designed in a way to better train science teachers (Siew et al., 2015; Wang et al., 2011). Finally, it is thought that it would enrich the literature to perform mixed studies for deeper and richer data are obtained by planning action research to observe science teachers' classroom practices for a long time.

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