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RESEARCH ARTICLE

Enhancing Digital Fluency Skills and STEAM Teaching Self-Efficacy of Teachers of Gifted Students Through Digitally Supported STEAM Learning

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ABSTRACT

The purpose of this research is (a) to determine the effect of a six-day-long professional development workshop called as "digitally supported STEAM learning" on the digital fluency skills and STEAM teaching self-efficacy of gifted students' teachers and (b) to reveal the views of teachers on different aspects of "digitally supported STEAM learning." In this mixed-method research with an embedded design, the data were collected from 20 teachers working in Science and Art Centers where gifted students study in different cities of Türkiye. Quantitative data were collected through the Digital Fluency Scale and Teacher Self-Efficacy Scale for STEAM Practices while qualitative data were gathered through audiotaped semi-structured focus group interviews. The quantitative data were analyzed performing the Wilcoxon signed-rank test while the qualitative data were content analyzed by using inductive coding. As a result of this research, it was found that "digitally supported STEAM learning" caused a significant increase in the digital fluency skills and STEAM teaching self-efficacy of teachers of gifted students. Also, it was understood from focus group interviews that because of "digitally supported STEAM learning," the teachers of gifted students learned the content of STEAM, how to integrate technology and education.

It is important to provide the gifted students, who make up 2% of the society and learn faster than their peers, with opportunities to learn according to their interests (Rogers 2007; Sak 2004) and to provide special trainings so that they can develop themselves at a higher level (Subotnik et al. 2011). Gifted students outperform their peers in higher-level thinking skills, productivity, motivation, independent work, science, art, and design skills (Davaslıgil 2004), and effective use of technology (Kurnaz and Tepe 2019). This highlights the importance of implementing science, technology, engineering, art, and mathematics (STEAM) education (Yakman and Lee 2012) for gifted students. However, there is no doubt that the effectiveness of the education in question can be directly proportional to the competencies of the teachers in this regard. When the studies on the subject are examined, the findings about the most basic competencies that teachers of gifted students should have are to provide students with high-level cognitive skills in the right time and place and to cooperate with internal/external stakeholders on the measures to be taken and strategies to be followed in the development of students (Dağlıoğlu 2010); for this, teachers of gifted students should be trained according to appropriate teaching approaches (Kurnaz and Arslantaş 2018; Tüzün and Tüysüz 2018). Therefore, with developing both the skills of teachers of gifted students to use digital tools effectively and efficiently and their

Abbreviations: BİLSEM, science and art center; STEAM, science, technology, engineering, arts and math; STEM, science, technology, engineering, and math.

professional competencies for STEAM education, where different disciplines are used together, it will be possible to ensure that teachers can meet the needs of gifted students at the highest level possible. To achieve this, it is vital to evaluate the impact of such trainings on teachers' related skills as well as teaching self-efficacy.

1 | Literature Review

1.1 | STEAM Teaching Self-Efficacy

Considered as a part of Bandura's (1986) social cognitive theory, self-efficacy is defined as an individual's beliefs about their ability to accomplish a task (Bandura 1997); it focuses on the individual's potential for actions that they can do instead of what they actually do (Klassen and Chiu 2010). Self-efficacy, which is specific to a certain goal or domain, is assessed by rating the individual's self-confidence in reaching the goal (Kelley et al. 2020). Teacher self-efficacy is defined as teachers' beliefs about their ability to achieve desired results in the teaching-learning process (Tschannen-Moran and Woolfolk Hoy 2001). Teaching self-efficacy is the teacher's belief in performing the teaching function effectively (Geijsel et al. 2009). Teacher self-efficacy regarding STEM practices is defined as teachers' beliefs about helping their students acquire science, technology, engineering and mathematics skills (Yaman et al. 2018). Based on this definition, STEAM teaching self-efficacy, which was determined as a variable in the research, can be defined as the teacher's belief in teaching the integration of science, technology, engineering, art, and mathematics disciplines effectively. It is believed that this integration can be achieved successfully with teachers who have high STEAM teaching self-efficacy beliefs. Teachers' beliefs about planning, implementing and evaluating activities by using their knowledge and skills in different disciplines are directly related to their competencies in these subjects (Karakaya and Yılmaz 2022). As Yaman et al. (2018) argue, it is important for teachers to have detailed knowledge about STEAM or to have done STEAM-related activities in order to develop STEAM teaching self-efficacy. In addition, based on the facts that teachers' self-efficacy affects their classroom practices, behaviors, and performances (Davis et al. 2006), STEAM content can be conveyed better depending on teachers' self-efficacy (Nadelson et al. 2012); it can be argued that STEAM teaching self-efficacy plays a key role in the planning and implementation of activities that allow students to think multi-dimensionally and discover their talents, and in achieving learning goals. Thus, as Aabla (2017) states, STEAM education helps gifted students acquire knowledge and create innovative products, as well as develop twenty-first century skills such as communication and cooperation. One of these skills is digital fluency, which will be explained in more detail below.

1.2 | Digital Fluency

While digitalization brings individuals, cities, countries, and continents together and increases individual and social potential, it causes living in a more complex and uncertain world (Schleicher 2018). With each new technology, the skills that individuals need to have differ as well as the knowledge. For example, virtual and augmented reality technologies require basic knowledge and use of mobile devices/applications (Demir 2018). As Harel (2016) states, it is not considered sufficient for individuals to have reading, writing, and math skills in developing economies, and being a global citizen in the twenty-first century is determined by computer science. In this context, the concept of digital fluency comes to the fore as an important competence area (Chou and Chiu 2020; Demir 2018; Miller and Bartlett 2012). Digital fluency requires knowing when and where to use technology (Fields and Hartnett 2018; Wei et al. 2020). With the integration of information technologies into schools, new opportunities have emerged to support students' learning (Soffer and Yaron 2017), and it has become crucial for students to have digital fluency skills (Chou and Chiu 2020; Miller and Bartlett 2012). However, it has become vital for teachers as well as students to have the ability to use digital tools, and in recent years, studies on digital fluency in the context of education have gained momentum (Demir 2018; Miller and Bartlett 2012; Pinho and Lima 2013) because while education is rapidly digitalizing in the world, the perception of online learning has also changed, and educational practices supported by digital tools have become a necessity rather than an option. In the period when face-to-face education was suspended in schools during the COVID-19 pandemic, which spread worldwide in 2020, the need for innovative practices in the field of education increased, and in studies on the use of digital tools in education (Dhawan 2020; Korkmaz and Toraman 2020; Paudel 2021; Williamson et al. 2020), situational analyses toward new education paradigms were done. While the findings obtained from these studies emphasize the need for innovative practices in the education process, the development of teachers' competencies within the scope of twenty-first century skills is also mentioned. In addition, as a result of the research conducted by Wannapiroon and Pimdee (2022), it was determined that STEAM education supported by digital tools had positive effects on students' innovative behaviors by improving their creative thinking skills.

1.3 | Significance and Purpose of the Research

Studies on STEAM education with teachers in Türkiye (Beşkese 2019; Kahya and Özdilek 2021; Şat 2023; Tüzün and Tüysüz 2018; Uştu 2019), have been carried out since 2018. In these studies, in which mostly qualitative research method was used, the opinions of teachers about STEAM education and STEAM teacher's competencies were investigated. These studies were carried out mostly with the teachers of gifted students, who are science teachers. Aside from these findings, a few studies revealed that pre-service teachers had higher levels of self-efficacy for STEM practices (Ozkaya et al. 2022). However, there is still a need for research on teachers' self-efficacy for STEM practices. There are also a limited number of studies on teachers' digital fluency skills in Türkiye. Digital fluency skills of teacher candidates varied greatly depending on their gender, department, grade level, foreign language proficiency, high school graduation, and type of technology utilized (Demir 2018). Technology integration self-efficacy perceptions of teacher candidates were found to be a significant predictor of their digital competence levels (Kaya and Uyangör 2022). Digital fluency teacher training program was also found to be effective in improving primary school teachers' digital fluency levels (Altunkaynak 2022). Karakuş and

Kılıç (2022) revealed that digital awareness and competence of pre-service teachers significantly predicted and explained 62% of the variance in their digital fluency. Durmus Cemcem et al. (2023) discovered that pre-service teachers' digital citizenship was a strong predictor of their digital fluency and wisdom. Özmen and Bulut Özek (2023) found a positive and moderate correlation between pre-service teachers' digital fluency and attitudes toward online learning. Özerbaş and Buz (2024) found that digital fluency levels among university students in Kyrgyzstan varied by gender, age, and department. Therefore, the need for research on digital fluency skills in Türkiye has emerged. On the other hand, no previous research has been found in the literature that reveals the contribution of a professional development workshop called as "digitally supported STEAM learning" to the digital fluency skills of teachers of gifted students. This study focuses solely on professionalizing gifted students' teachers in STEAM teaching through the use of digital resources in order to satisfy the special demands of gifted students who are much ahead of their peers. When the studies in the relevant literature are reviewed in general, the use of digital tools in STEAM education, which is the focus of this research, will enable teachers of gifted students to make more effective use of technology. In this context, the aim of the research is to determine the contribution of digitally supported STEAM learning to the digital fluency skills and STEAM teaching self-efficacy of teachers of gifted students. The questions to be answered in the research are:

1. Does digitally supported STEAM learning have a significant effect on the digital fluency skills and STEAM teaching self-efficacy of teachers of gifted students?
2. What are the views of gifted students' teachers on digitally supported STEAM learning?

2 | Methods

2.1 | Research Design

This mixed methods study, which employed both quantitative and qualitative research methodologies, had a concurrent nested (embedded) design. In the concurrent nested (embedded) design, quantitative and qualitative data are collected and analyzed at the same time. This design is useful when it is desired to gain a broad perspective on the subject under investigation and to conduct research with different groups or levels (Creswell 2008). In the concurrent nested (embedded) design, "*… one data set provides a supportive, secondary role in a study …*" (Creswell and Plano-Clark 2011, p. 91). In this research, qualitative data played a supporting role. In other words, the qualitative data are embedded in the quantitative data as shown in Figure 1.

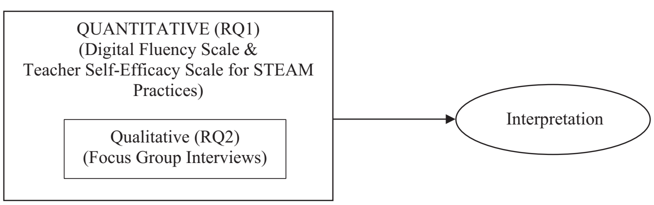

FIGURE 1 | Research model.

In the study, quantitative data were collected through the Digital Fluency Scale (Demir 2018) and Teacher Self-Efficacy Scale for STEAM Practices (Yaman et al. 2018); qualitative data were obtained through audiotaped Focus Group Interviews. While these stages were kept separately in the analysis of the data, the findings were presented in a holistic way in the interpretation (Creswell 2014).

2.2 | Sampling

The study group consists of 20 teachers working in science and art centers from the fields of science, information technologies, technology and design, visual arts, and mathematics. In the determination of the study group, maximum variation and criterion sampling methods, which are among the purposive sampling methods, were used. Participants were required to have basic computer skills, be willing and interested in education, have at least 3 years of working experience with gifted students, conduct academic studies about gifted students, and participate in trainings. Since STEAM education includes different disciplines, this situation was taken into account in the selection of the target audience. In order to ensure maximum variation, it was decided that it would be appropriate for teachers from all fields of STEAM to take part in the study. In addition, as it is aimed to deliver STEAM activities to students in different regions and provinces within the scope of the research, attention was also paid to the selection of the participants from different provinces in Türkiye's seven geographical regions (Adana, Adiyaman, Aksaray, Denizli, Gaziantep, Erzurum, Hakkari, Hatay, Istanbul, Izmir, Konya, Mardin, Mersin, Mugla, Ordu). The participant teachers were mostly female and had an average of 3.6 years of teaching experience. Their age ranged from 29 to 49, with a mean of 36.75 ($SD = 5.36$). Teachers received training in STE(A)M teaching, coding and robotics, as well as the use of digital resources (e.g., Web 2.0 tools) and applications through in-service trainings and nationally funded projects.

2.3 | Context of the Research

In Türkiye, the first Science and Art Center (BİLSEM) was established in Ankara in the 1994–1995 academic year in order to implement a differentiated curriculum so that gifted students can realize their own potential and benefit themselves and society. In these institutions, students who are diagnosed as gifted in primary school 1st, 2nd, and 3rd grades are entitled to study from primary school to university age (Vuran and Ünlü 2013). Teachers working in Science and Art Centers are also selected according to criteria such as professional competence, academic studies, pedagogical content knowledge, project experience, and technological knowledge. As of the 2022–2023 academic year, there are 355 BİLSEMs in Türkiye. Taştepe and Sarı (2022) found that over two-thirds of teachers at Science and Art Centers received gifted education and had at least 3 years of teaching experience. Topcu (2022) explored the meanings teachers working in science and art centers attributed to being a teacher of a gifted student and concluded that they characterized being a gifted student's teacher as being innovative, guiding, effective, and professionally fulfilled while also feeling oppressed and constrained.

2.4 | Digitally Supported Learning

Digitally supported STEAM learning was carried out theoretically and practically. In this context, theoretical and practical trainings were given to the participating teachers in the first 2 days in subjects such as Introduction to STE(A)M Education, Entrepreneurship in STE(A)M and Curricula, 3D in Engineering and Design, Engineering Design Process, Planning A STEAM Lesson Using the 5E Instructional Model, Technology Integration in Education, Game and Gamification/Animation, Digital Story-Making, Material Design with Augmented Reality, The Role of Art in STEAM Education and Biomimicry in Product Design. Starting from the third day, the participant teachers were asked to design a "Sustainable Living Space on Mars" based on the scenario (adapted on 15.12.2020 from Wilkerson, n.d.) in connection with all they learned in the first 2 days. The 5E lesson plan implemented throughout the practical part of the teacher training was Appendix A.

During the evaluation phase, promotional products (posters, public service announcements, short films, posters, commercials, etc.) regarding "A Sustainable Living Space on Mars" prepared in teacher groups were presented in order. On the sixth and last day, expert academics from the project team evaluated the performances and designs of the teacher groups related to the living space using product evaluation rubrics that included the criteria (suitability for the design process, functionality, economy, ergonomics, sustainability, originality, aesthetics, meeting people's needs, suitability for STEAM lesson objectives, group work and presentation) determined by the collaboration between academics and teachers. As a result of the scoring, the group with the highest score was determined according to the ranking of the groups and awarded. Photographs representative of the stages of the engineering design process are shown in Figure 2.

2.5 | Data Collection Tools

2.5.1 | Digital Fluency Scale

The scale developed by Demir (2018) to determine the digital fluency levels of teachers consists of a total of 29 items and three sub-dimensions (awareness, self-efficacy, affective). Sample items of the scale, which were answered in a 5-point Likert type as *I totally disagree*, *I totally agree*, are as follows: "I can decide when digital tools will work," "I can use digital tools without any problems," and "I can be a role model in using digital tools." The Cronbach alpha internal consistency coefficient of the overall scale was calculated as 0.75.

2.5.2 | Teacher Self-Efficacy Scale for STEAM Practices

The scale developed by Yaman et al. (2018) to determine teachers' self-efficacy for STEM practices consists of a total of 18 items and a single dimension. Each item of the scale was slightly reworded by the researchers adding "A" to "STEM." The sample items of the scale, which are answered in a 5-point Likert type as *never*, *always*, are as follows: "I can design a good activity related to STEAM," "I feel competent in STEAM practices," and "I can easily explain the steps I take in STEAM activities to my students." The Cronbach alpha internal consistency coefficient of the overall scale was calculated as 0.91.

2.5.3 | Focus Group Interview Form

A semi-structured interview form containing eight questions was created in order to thoroughly examine the participants' views on digitally supported STEAM learning. The purpose of the created form is to reveal their experiences and opinions about the project by conducting focus group interviews with the participants. Some of the questions in the form are as follows: (a) What does STEAM mean to you?; (b) What is STEAM? Can you explain?; (c) What are your views on integrating art with STEM, starting from the project implementation process? The opinions of five field experts (science, information technologies, design/engineering, visual arts, and mathematics) covering different disciplines of STEAM education were taken in the preparation of the interview form. The form was finalized by making adjustments in line with the feedback given by the experts. The audiotaped interviews, which were held simultaneously by the project coordinator and three researchers in four groups of five teachers in the activity hall, lasted for an average of 25 min.

2.6 | Data Analysis

A statistical package program was used in the analysis of the collected quantitative data. Since the study group consisted of 20 teachers, the Wilcoxon signed-rank test, which is one of the non-parametric tests, was used in the analysis of quantitative data (Rosner et al. 2006). By comparing the pre-test and post-test scores obtained with the scales, evaluations were made regarding the significance of the effect of digitally supported STEAM learning on the digital fluency skills and STEAM teaching self-efficacy of the teachers of gifted students. The pre-test was given to teachers at the start of the six-day professional development workshop, while the post-test was administered at the end. The data collected through audiotaped focus group interviews were content analyzed by using the inductive category development approach. During the analysis of the qualitative data, the answers given by the participants in the focus groups for each question were carefully read, and the similarities and differences between the views were determined. Some precautions were taken to ensure the validity and reliability of the qualitative data (Merriam and Tisdell 2016). First of all, a model suitable for the purpose of the research was used, and credibility was tried to be supported by directly quoting the statements of the participants in the findings. In order to ensure reliability, the intercoder agreement technique was used. In this context, some of the data were coded independently by two researchers, and the intercoder agreement coefficient for the coded data was calculated as 0.87 using the formula put forward by Miles and Huberman (1994). A concordance between co-coders above 0.70 means that reliability is provided (Miles and Huberman 1994).

2.7 | Ethical Considerations

The necessary research permission was obtained with the Commission decision dated 21/02/2022 and numbered 42580591 of Gaziantep Provincial Directorate of National Education. In

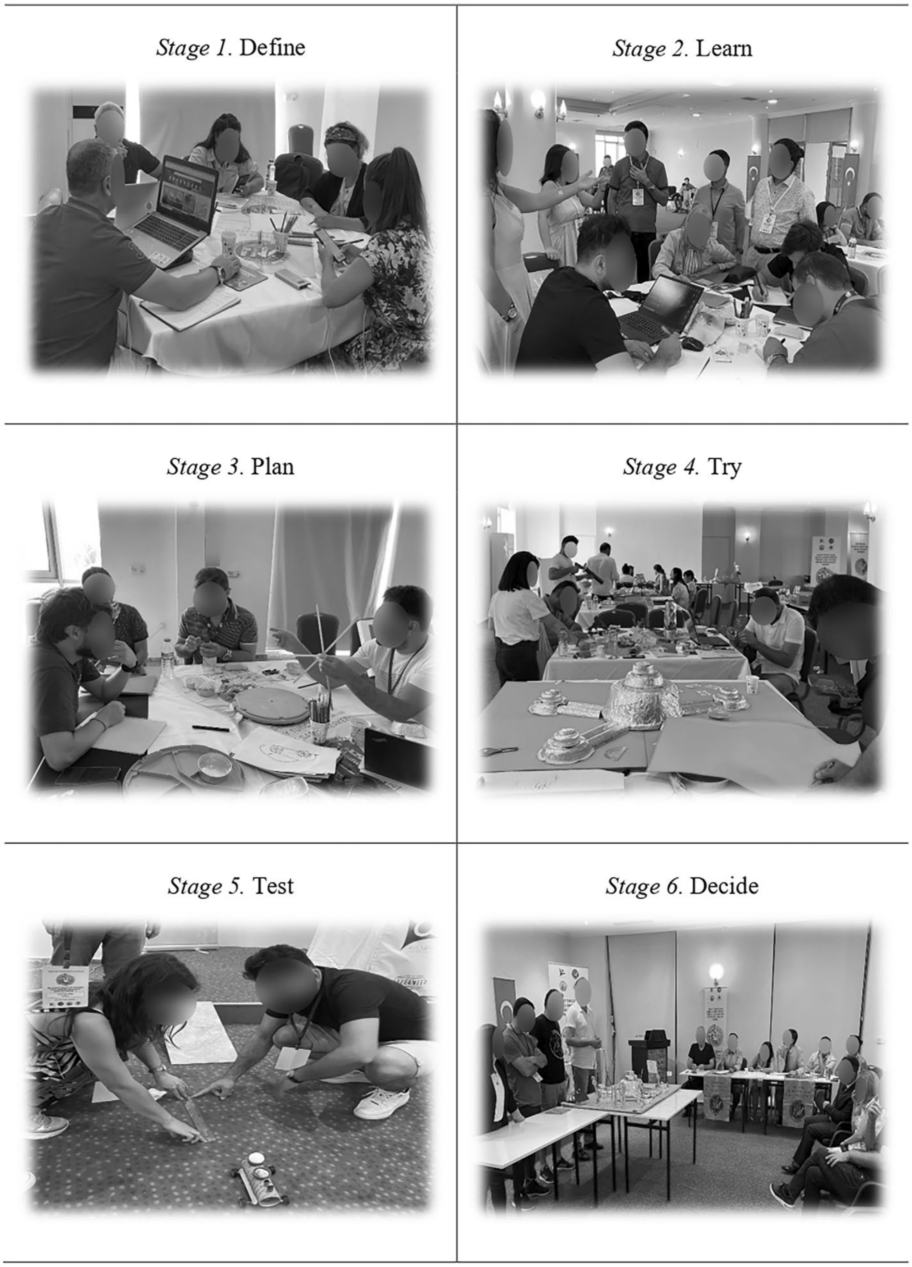

FIGURE 2 | Photographs representative of the stages of the engineering design process.

order not to encounter any ethical problems during the research process, the principles of informed consent, respect for the anonymity of participants, not harming the physical and mental health of the participants, not deceiving/misleading, and sticking to the data (Yıldırım and Şimşek 2018) were taken into consideration. Participating teachers were informed about the purpose, duration, and potential risks of the study with an informed consent form. Thus, the principle of not deceiving/misleading is provided. Permission was obtained from the teachers to collect data through scales and interviews, and to use a voice recorder in focus group interviews. Confidentiality of the participants was ensured by reporting the findings with pseudonyms given to each teacher. The research did not include any practice that would threaten the physical and mental health of the participants. In order to adhere to the data, all the data collected within the scope of the research were reported without any falsification.

3 | Findings

3.1 | Quantitative Findings

The results obtained from the Wilcoxon signed-rank test, which was conducted to determine the effect of digitally supported STEAM learning on the digital fluency skills and STEAM teaching self-efficacy of teachers of gifted students, are presented in Table 1.

As seen in Table 1, teachers' pre-test mean score of Digital Fluency Scale is $M = 3.29$ (SD = 0.20), post-test mean score is

$M = 4.26$ (SD = 0.35); the pre-test mean score of the Teacher Self-Efficacy Scale for STEAM Practices is $M = 3.25$ (SD = 0.43), and the post-test mean score is $M = 4.39$ (SD = 0.54). It is seen that the post-test mean scores of the teachers are statistically significantly higher than the pre-test mean scores. Based on these results, it can be said that digitally supported STEAM learning taught in this particular professional development workshop causes a significant increase in the digital fluency and STEAM teaching self-efficacy of teachers of gifted students.

3.2 | Qualitative Findings

Eight themes shown in Figure 3 were produced as a result of the content analysis of the data obtained from the focus group interviews on digitally supported STEAM learning with the teachers of gifted students. Qualitative findings are presented under each theme produced below, supported by direct quotations.

TABLE 1 | Mean, standard deviation and significance values of teachers' pre-test and post-test scores.

		N	*M*	SD	*p*
Digital fluency	Pre-test	20	3.29	0.20	0.000***
	Post-test	20	4.26	0.35	
Teacher self-efficacy for STEAM practices	Pre-test	20	3.25	0.43	0.000***
	Post-test	20	4.39	0.54	

***$p < 0.001$.

3.2.1 | Teachers' Learning Outcomes as a Result of Digitally Supported STEAM Learning

In the first theme, it was tried to determine the opinions of the teachers about what they learned in the project. When teachers' views on this theme are examined, they stated that they obtained knowledge on subjects such as learning the content of STEAM, integrating technology and education, learning and applying new digital programs and tools, and planning STEAM activities with digital tools.

3.2.1.1 | Learning the Content of STEAM.

The opinions of some teachers who stated that they had the opportunity to learn about the content of STEAM and that they learned the details of STEAM and how they could improve their engineering and entrepreneurial skills with STEAM are given below:

> .... the importance of engineering and entrepreneurship practices in planning STEAM activities, and what needs to be done while paying attention to artistic design
>
> (Zoey, Focus Group 1).

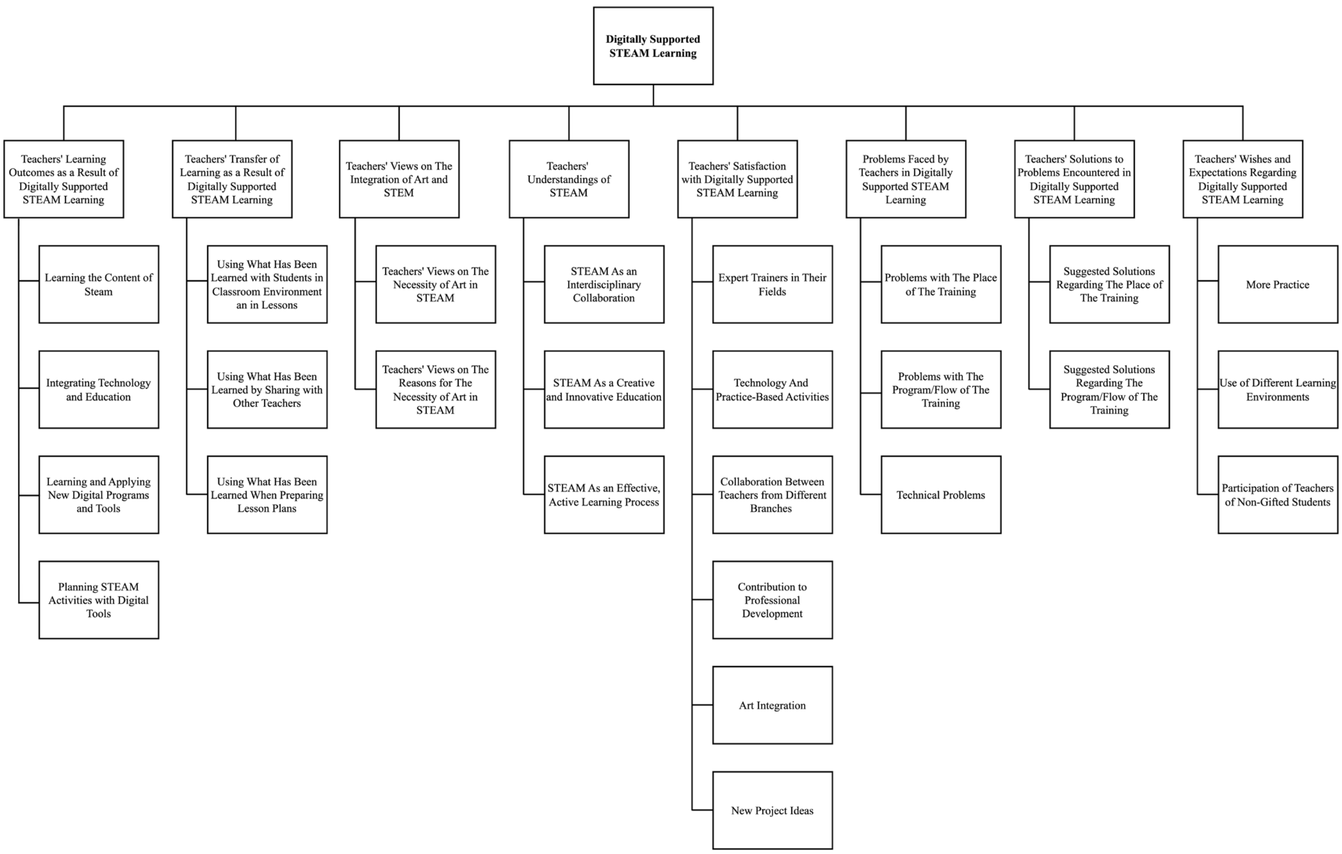

FIGURE 3 | Visual representation of sub-themes and themes generated as a result of content analysis.

3.2.1.2 | Integrating Technology and Education. Expressing that they learned why and how technology and education should be integrated, most teachers expressed their thoughts on "integration of technology and education" as follows:

> We learned different things about how to integrate technology, which has become indispensable in today's conditions, with education and how it can be used in education
>
> (Rachel, Focus Group 3).

3.2.1.3 | Learning and Applying New Digital Programs and Tools. Most of the views of the teachers on "learning and applying new digital programs and tools," who stated that they learned to use some digital programs (such as Fusion 360, 4D applications) and tools (3D printers) in the engineering design process, are as follows:

> We learned about the Fusion 360 program, that STEAM activities are very important for engineering and that different materials can be used in 3D printers
>
> (Max, Focus Group 3).

3.2.1.4 | Planning STEAM Activities With Digital Tools. The opinions of most teachers who stated that they learned about "planning STEAM activities with digital tools" during the project implementation process are as follows:

> We learned how we can benefit from digital tools while designing an activity related to STEAM that includes more than one area
>
> (Mark, Focus Group 2).

3.2.2 | Teachers' Transfer of Learning as a Result of Digitally Supported STEAM Learning

In the second theme, it was tried to examine where and how the knowledge obtained in the project would be used. Some of the prominent responses were as follows: Using what has been learned with students in the classroom environment and in lessons, using what has been learned by sharing it with other teachers, using what has been learned while preparing a lesson plan.

3.2.2.1 | Using What Has Been Learned with Students in the Classroom Environment and in Lessons. Most of the teachers stated that they could use what they learned as a result of digitally supported STEAM learning with students in the classroom environment and in lessons. Some of the views on this subject are:

> I plan to use the knowledge I have gained here in the classes I teach at my school. In addition, the facilities of the school are suitable for providing this education. Being advantageous in terms of the number of students will make it easier for us to implement this education
>
> (Nolan, Focus Group 3).

3.2.2.2 | Using What has Been Learned by Sharing with Other Teachers. Some teachers stated that they will use what they have learned by sharing with other teachers after digitally supported STEAM learning. Teachers' views on this subject are as follows:

> When I go to school, I plan to prepare projects with my colleagues from different fields and to support students
>
> (Max, Focus Group 3).

3.2.2.3 | Using What has Been Learned When Preparing Lesson Plans. A few teachers expressed their opinions about using what they learned in digitally supported STEAM learning while preparing a lesson plan. These opinions are as follows:

> In terms of technology and knowledge, gifted students are at a better level than their peers. Therefore, we need lesson plans that we can make by supporting such STEAM activities with digital tools. Thanks to the project, we got an idea on how to make this plan
>
> (Mary, Focus Group 2).

3.2.3 | Teachers' Views on the Integration of Art and STEM

In the third theme, the opinions about the integration of art with STEM were examined, and it was determined that the teachers expressed their opinions about the necessity of art in STEAM and the reasons for the necessity of art in STEAM.

3.2.3.1 | Teachers' Views on the Necessity of Art in STEAM. In the focus group interviews, most of the teachers stated that integrating art with STEM is important and necessary. Some of these views can be listed as follows:

> Since I believe that art should be in everything, I definitely find it right and necessary to integrate it with STEM
>
> (Tara, Focus Group 1).

> The art field needs to be added to STEM and given importance. Because no matter how a beautiful thing you think, something will be missing when art and aesthetics are ignored
>
> (Ann, Focus Group 4).

3.2.3.2 | Teachers' Views on the Reasons for the Necessity of Art in STEAM. In addition to the teachers who stated that art is important and should be included in STEM practices, some teachers who emphasized that products (i.e., sustainable living spaces on Mars) created by the teachers gain originality and functionality with art expressed their thoughts as follows:

> .... important that STEM becomes STEAM. Of course, it is important for something to be useful; besides, making that thing from an aesthetic point of view will both increase the use of that thing and make it enjoyable. From this perspective, biomimicry becomes indispensable
>
> (Max, Focus Group 3).

The opinions of some teachers who stated that more aesthetic products are designed with different perspectives with the inclusion of art in STEM activities are presented below:

> Art is an indispensable part of our lives. We should include this in our lessons or the projects we do, of course, the work we do should have an aesthetic aspect, they should be appealing to the eye
>
> (Barbara, Focus Group 4).

3.2.4 | Teachers' Understandings of STEAM

In the fourth theme, teachers' understandings of the STEAM concept were examined. Sub-themes that stand out from the answers given can be listed as follows: STEAM as an interdisciplinary collaboration, STEAM as a creative and innovative education, STEAM as an effective and active learning process.

3.2.4.1 | STEAM as an Interdisciplinary Collaboration. It was observed that some of the teachers emphasized that STEAM is an approach based on interdisciplinary collaboration and that the activities are planned and implemented in this way, and that the products gain meaning by using the knowledge from different disciplines together. The opinions on this matter are as follows:

> STEAM reminds me more of collaboration. It explains that a good product will emerge with the cooperation of different disciplines. A single discipline alone is not enough to produce a product. In my opinion, one of the most important twenty-first century skills are collaboration, and STEAM gives us the opportunity to do this very well and correctly
>
> (Miriam, Focus Group 4).

3.2.4.2 | STEAM as a Creative and Innovative Education. Some teachers who stated that STEAM evokes creative and innovative educational environments expressed their thoughts as follows:

"With the integration of art with science, learning, development and creativity will be enhanced even more. STEAM is a teaching method that includes science, technology, engineering and art" (Mark, Focus Group 2).

3.2.4.3 | STEAM as an Effective, Active Learning Process. Stating that STEAM means effective learning, active participation in the teaching-learning process, a few teachers emphasized that the use of STEAM activities in the classroom is important in terms of creating effective learning environments by ensuring the active participation of students in the process. They expressed their views on this issue as follows:

> STEAM enables more effective learning by allowing more than one teacher to do practice together
>
> (Nolan, Focus Group 3).

> STEAM is an education that enables students to actively participate in the education process and to design and interpret something, and to use their knowledge from different disciplines together
>
> (Adam, Focus Group 2).

3.2.5 | Teachers' Satisfaction With Digitally Supported STEAM Learning

Within the scope of the fifth theme, teachers' views on the pleasurable aspects of digitally supported STEAM learning were examined, and it was determined that they were satisfied with digitally supported STEAM learning on subjects such as expert trainers in their fields, technology and practice-based activities, cooperation between teachers from different branches, contribution to professional development, art integration, and new project ideas.

3.2.5.1 | Expert Trainers in Their Fields. The opinions of almost all teachers who expressed their satisfaction with the fact that digitally supported STEAM learning is carried out by "expert trainers" are as follows:

> It was instructive and productive for me to include the experiences of experts in many fields and present it as a point in life
>
> (Amir, Focus Group 1).

3.2.5.2 | Technology and Practice-Based Activities. The inclusion of technology and practice-based activities in digitally supported STEAM learning enabled teachers to actively participate in the process and gain a positive perspective on learning. Opinions on this subject can be listed as follows:

> Doing practice was important for the retention of the knowledge we learned. The thought of getting help from our friends in places where we had difficulties from time to time also motivated us
>
> (Adam, Focus Group 2).

3.2.5.3 | Collaboration Between Teachers From Different Branches. Another issue in which almost all teachers expressed their satisfaction was that teachers from different branches take part in the groups in digitally supported STEAM learning.

> "All stages of training and presentations were satisfactory. In addition, defining the problem, following the stages of practice and coming together with colleagues from different branches to create and present products were exciting"
>
> (Max, Focus Group 3).

3.2.5.4 | Contribution to Professional Development. Some teachers stated that the outcomes of digitally supported STEAM learning contribute to their professional development as follows:

> I had little knowledge of digital tools and tried to use them as much as possible in my lessons. However, here I learned new applications, new teaching methods and concepts that I did not know. Of course, this contributed to my professional development. I have already set a goal of applying what I learned after the project and doing some more in-depth research
>
> (Mark, Focus Group 2).

3.2.5.5 | Art Integration. In the interviews, it was stated by most teachers that adding an art dimension to STEAM activities within the scope of digitally supported STEAM learning is a positive aspect. The teachers' views on this issue are as follows:

> Before the project, I knew the concept of STEM, I was doing activities, but we received both theoretical and practical training on the fact that art has a special place and should definitely be included in the activities we will do in the project
>
> (Barbara, Focus Group 4).

3.2.5.6 | New Project Ideas. Some teachers who think that the activities carried out during digitally supported STEAM learning will make significant contributions to new project ideas and see this positively, expressed their thoughts as follows:

> Thanks to the project, I plan to do projects with my students with the knowledge and skills I have gained. I am thinking of preparing research projects especially on STEAM
>
> (Adam, Focus Group 2).

3.2.6 | Problems Faced by Teachers in Digitally Supported STEAM Learning

In this theme, teachers' views on whether they encountered any problems during the project were examined. Teachers, who stated that they did not experience any problems in general, referred to problems with the place of the training, problems with the program/flow of the training, and technical problems.

3.2.6.1 | Problems With the Place of the Training. The opinions of some teachers, who found the hotel, where digitally supported STEAM learning is provided, far from the city center, are as follows:

> The fact that the hotel is far from the city center, transportation problems, and the length of the theoretical trainings affected my attention span and learning a little bit
>
> (Tara, Focus Group 1).

3.2.6.2 | Problems With the Program/Flow of the Training. Another problem that some teachers have expressed is that the program/flow of digitally supported STEAM learning is intensive. The opinions on this matter are as follows:

> The intensity of the program can be reduced a little and it can be finished earlier in the evening
>
> (Sam, Focus Group 2).

3.2.6.3 | Technical Problems. In the interviews, a few teachers expressed that minor technical problems were encountered from time to time in digitally supported STEAM learning as follows:

> Sometimes the Internet connection got weak or lost while downloading the programs. This situation caused us to install the program a little late, but since the sizes of the applications we used were small, we handled it in a short time
>
> (Mark, Focus Group 2).

3.2.7 | Teachers' Solutions to Problems Encountered in Digitally Supported STEAM Learning

In this theme, where the opinions of the teachers about the solutions for the problems they encountered during the project were examined, it was determined that the teachers developed their suggestions about the problems with the place of the training and problems with the program/flow of the training.

3.2.7.1 | Suggested Solutions Regarding the Place of the Training. A few teachers stated their suggestions regarding the place of the training as follows:

> Accommodation could be provided in a more central location. Instead of many subjects, it could have been deepened in less but more specific areas of need
>
> (Tara, Focus Group 1).

3.2.7.2 | Suggested Solutions Regarding the Program/Flow of the Training. Some teachers expressed their suggestions regarding the program/flow of the training as follows:

> ...more time can be given to practice
>
> (Harley, Focus Group 4).

3.2.8 | Teachers' Wishes and Expectations Regarding Digitally Supported STEAM Learning

Teachers' wishes and expectations regarding digitally supported STEAM learning were gathered under the sub-themes of more practice, use of different learning environments, and participation of teachers of non-gifted students.

3.2.8.1 | More Practice. Most teachers expressed their wishes and expectations for spending more time on practice in digitally supported STEAM learning as follows:

> After each presentation where the STEAM stages are explained, I would like to add an activity related to that subject. For example, if the 5E model is explained, a lesson plan can be designed immediately
>
> (Nolan, Focus Group 3).

> ... more time should be devoted to practice
>
> (Ellie, Focus Group 2).

3.2.8.2 | Use of Different Learning Environments. One of the teachers wished different learning environments (e.g., a factory) would have been used in digitally supported STEAM learning as follows:

> I think it can be more effective if the educational spaces are differentiated, such as seeing the engineering dimension in place in a factory
>
> (Amir, Focus Group 1).

3.2.8.3 | Participation of Teachers of Non-Gifted Students. One more teacher wished teachers of non-gifted students would have participated in digitally supported STEAM learning as follows:

> ...It would be nice to continue by revising the content of the training. It would be better to carry out a project in which teachers of non-gifted students would participate, or at least to carry out the training by allocating certain quotas to teachers of both gifted and non-gifted students
>
> (Rachel, Focus Group 3).

4 | Discussion, Conclusion, and Recommendations

As a result of this research, it has been determined that digitally supported STEAM learning contributed to the development of digital fluency skills and STEAM teaching self-efficacy of teachers of gifted students. As a matter of fact, the development of digital skills is considered an important component of STEAM environments (Krüger Mariano and Chiappe 2021). In addition, STEAM learning activities increase the creative thinking competencies of individuals by developing digital skills (Leroy and Romero 2021). In this context, it can be argued that digital fluency skills are important in the process of implementing STEAM activities and that STEAM education will have positive reflections on the development of digital fluency skills. In the literature, it has been determined that STEAM education can be better provided by the use of digital technologies (e.g., gamification, animation, augmented reality, and virtual reality), and that STEAM education, which is supported by digital tools and includes activities from different disciplines, is more effective than activities for a single discipline (Chujitarom and Piriyasurawong 2019). In addition, in this study, it was concluded that digitally supported STEAM learning contributed to the development of STEAM teaching self-efficacy. In support of the result of this research, Zhou et al. (2023) also determined that professional development trainings improved K-12 STEM teachers' self-efficacy, and the effect size was large.

In the light of the findings from the interviews, it was concluded that teachers learned how to integrate STEAM's content, technology and education, implement new digital programs/tools and plan STEAM activities with digital tools and that they would use what they have learned with students in classroom environment and in lessons, share it with other teachers and use it while preparing lesson plans. But, it is important to remember that the facilities at the school and the class sizes affect how eager teachers are to use what they have learned in their classes. In studies on this subject, it was emphasized that teachers' knowledge and skills in terms of content, curriculum knowledge, instructional planning, and their ability to apply this knowledge and skills will also increase thanks to STEAM education (Kim and Kim 2016), and the use of digital tools is a supporting element of STEAM education (Lavicza et al. 2022). In addition, STEAM education is beneficial in helping teachers learn innovative educational technologies and increase their digital competencies (Hlukhaniuk et al. 2020; Topalska 2021), and it is stated that the use of digital tools in activities (gamification, creating a digital story, etc.) to be carried out in STEAM education will have positive effects on student success (López et al. 2021). In another finding obtained from the interviews, it was emphasized that art is necessary and important in product design in STEAM due to originality, functionality, and aesthetics. In support of this finding, it was determined that with the inclusion of art, more original products can be created by combining scientific efforts with creativity and imagination (Marmon 2019; Shukshina et al. 2021), and the integration of art encourages creative solutions and products (Henriksen 2014; Sousa and Pilecki 2013). The teachers also interpreted STEAM as an interdisciplinary collaboration, a creative and innovative education, and an effective and active learning process. Since the digitally supported STEAM learning environment that teachers were offered to experience is an interdisciplinary, creative, inventive, effective, and efficient learning environment, this finding may be interpreted as predicted. How teachers conceptualize STEAM education might be accounted for by their high STEAM teaching self-efficacy and/or STEAM content knowledge because self-efficacy and content knowledge were found to influence the conceptualization of STEM education (Putra et al. 2021). Thanks to STEAM education, students work as a group with an interdisciplinary approach and actively participate in the learning process, and as a result, there is a noticeable increase in their academic success (Konyushenko et al. 2018 cited in Shukshina et al. 2021). Other topics discussed in the interviews were satisfaction with expert trainers, technology- and practice-based activities, cooperation between teachers from different branches, contribution to professional development, integration of art, and new project ideas. It is considered important in terms of professional development to bring together and train teachers from different fields to develop the digital competence of teachers and to create and support a STEAM-based educational environment in schools (Soroko and Mykhailenko 2019). To achieve this, opportunities should be given for teachers to work in a practice-based, collaborative, innovative, and thought-provoking learning environment. In addition, if the beliefs, perceptions, and voluntary efforts of teachers can be increased with STEAM teacher training to be given by experts in the field, STEAM education in schools will be encouraged (Kim and Lee 2018). In the interviews, it was understood that the problems experienced by the teachers were related to the place of the training, program/flow, and technical issues; they found solutions to the problems with the place as well as the program/flow of the training, they suggested that the location of the training could be more central, and the program/flow of the training could be of longer duration allowing for more practice; they had reasonable expectations regarding allocating more space to practice in the training, using different learning environments, and ensuring the participation of teachers of non-gifted students that would increase the widespread impact of the training. Teachers' suggestions and expectations can be taken into consideration in future projects. Since it is suggested in the literature that many teachers portray themselves as those who have higher self-efficacy beliefs than they actually have (Wheatley 2005), it can be said that the results related to teachers' STEAM teaching self-efficacy should be interpreted carefully. Other reasons for caution in interpreting the findings include the fact that the quantitative data collection tools used were self-report scales. Another limitation of this mixed methods research is that its quantitative findings are difficult to generalize due to the small sample size. Although generalizing findings is not the aim of the qualitative part of this research, the qualitative findings of this research can be generalized, albeit limitedly, to comparable situations and contexts (Yıldırım and Şimşek 2018) including teachers of gifted students. Based on the results of this research, the following suggestions can be made for practice and future research: Digitally supported STEAM learning can be provided in schools to improve the digital fluency skills of gifted students. For this reason, teachers can be given professional development training on digitally supported STEAM learning. Further STEAM teacher training may now be organized in a more central location, with more time for practice, allowing for learning in a variety of contexts, and incorporating non-gifted students' teachers. In future studies, the effect of digitally supported STEAM learning on the digital fluency skills of a larger sample of gifted and non-gifted students or their teachers and/or on the variables to be determined (achievement, attitude, motivation, subject taught, self-efficacy, etc.) can be investigated using different research designs and data collection tools other than self-report scales. In addition, the relationships between the subscales of the digital fluency scale and the STEAM teaching self-efficacy scale can be further studied.

Author Contributions

S.A. and H.C. administered the scales. S.A., K.K., B.A., and N.D. conducted the focus group interviews and analyzed the data. S.A. wrote the manuscript. K.K., B.A., N.D., M.S., and H.C. reviewed the final manuscript. All authors read and approved the final manuscript.

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Ethics Statement

The necessary research permission was obtained with the Commission decision dated 21/02/2022 and numbered 42580591 of the Gaziantep Provincial Directorate of National Education.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix A

5E Plan of the Practical Part of the Digitally Supported STEAM Learning

Stage	Lesson	Duration	Practices	Goals	Digital Tools	Materials
Engage	Drawing attention	50 min	• Discussion of the scenario given to the teacher groups. • Interpretation of the news footage about Mars by the teacher groups.	Teachers will be able to talk about the problem, come up with research questions based on the problem	Using digital technologies to find information about the problem	For each group: A scenario provided via a letter, news videos on Mars For each participant: An engineering design notebook, at least two colored pencils
	Finding the research questions explaining the problem	50 min	• Looking at information from the scenario and Mars news videos to understand the problem of creating a new living space on Mars. • Writing research questions about living space in engineering design notebooks. For example, how will people get food on Mars? How will energy, water, and air be used? What types of vehicles will people use to get around? How will waste be managed on Mars?			
Explore	Searching for information	50 min	• Looking online for the basic features and structure of Mars. • Looking for ways to get to Mars and create a living space there using the Internet and printed materials. • Writing a short story about Mars using online tools for creating digital stories.	Teachers will be able to learn about the basic ideas for creating a sustainable living environment on Mars.	Create a story about the characteristics of Mars using digital storytelling tools.	For each group: A computer, various objects, two sheets of A2 paper, colored pencils
	Testing Making tables and graphs	50 min	• Doing tests using different materials. • Choosing materials to use in designing a living space on Mars. • Using tables and graphs to show the results, and writing them down in engineering design notebooks. • Sharing the results obtained by the teacher groups.	Teachers will be able to do tests, while thinking about how strong and long-lasting the materials are that people need to live in the designed space on Mars, use tables and graphs to show the results of the tests related to the design of living space on Mars.		For each participant: An engineering design notebook, at least two colored pencils
Explain	Explaining the data collected during the Engage stage	2×50 min	• Presenting research taken from printed and Internet sources on the structure of Mars, how living spaces are designed, and how we can travel to Mars. • Explaining the reasons behind and selecting the program to be used to create a story for the "most sustainable" living space design using the predetermined digital tools.	Teachers will be able to present research data about a living space on Mars, present research data about digital tools.	Using digital tools	For each group: A laptop computer For each participant: An engineering design notebook, at least two colored pencils

Stage	Lesson	Duration	Practices	Goals	Digital Tools	Materials
Elaborate	Performing cost analysis Designing a rubric	50 min	• Talking about the problems of living on Mars and how to solve them. • Checking what resources are available and how much they will cost. • Preparing a set of rules to assess teachers' performance taking their suggestions into account.	Teachers will be able to engage in group discussions concerning the knowledge-based life problem, conduct cost analyses to ascertain profit and loss, prepare a preliminary draft and assess it across various dimensions, document the test results in engineering design notebooks, and make suggestions to improve it through small-group discussions.	Designing materials using augmented reality Creating models using a 3D printer	For each group: Ruler, microfiber cloth, oilcloth tablecloth, square notebook, styrofoam foam, tape measure, natural and colored wooden ice cream stick, natural and colored wooden matchstick, silicone gun, silicone stick, modeling knife, scissors, wooden skewer, cardboard cup, wooden block, natural modeling white clay, straw, ball of colored rubber band, corrugated cardboard, chipboard slide, cylinder box, A4 craft paper, glue, aluminum foil, nylon rope, aluminum container, aluminum round container, oval-sided cake container and lid, PLA Filament, Arduino economic starter kit For each participant: An engineering design notebook, at least two colored pencils
	Designing materials using augmented reality	2 × 50 min	• Using augmented reality to design elements for the living space on Mars. • Assessing the draft in terms of the most sustainable living space.			
	Creating models with a 3D printer	2 × 50 min	• Using a 3D printer to create materials for the prototype of a living space on Mars, • Writing down the testing results of the prototype in the engineering design notebook, • Making improvements to the prototype based on suggestions made in small-group discussions.			
	Establishing the criteria for and creating a living space on Mars "Designing a Living Space on Mars: There is a Village in Space, and that Village is my Village"	5 × 50 min	• Focusing on the role of art in STEAM education and biomimicry in product design, creating three-dimensional products to solve a problem by using knowledge and skills from STEAM subjects. • Determining criteria for and creating a living space taking into account the features of the materials used, such as how long they will last, how well they work, how unique they are and how attractive they are.			
	Preparing promotional materials for "the most sustainable living space on Mars" project	3 × 50 min	• Using a 3D printer to create materials for the prototype of the living space on Mars. • Preparing promotional materials, such as posters, public spots, short films for the product(s) to be exhibited, • Creating a mockup of the living space and arranging it according to the specified criteria.			
Evaluate	Doing authentic assessment	2 × 50 min	• Presenting promotional materials such as posters, public spots, short films, ads prepared for the prototypes, • Assessing teacher groups' performance and designs through the rubric to be developed, • Selecting the most sustainable living space on Mars and announcing the winner.	Teachers will be able to prepare promotional materials such as posters, public spots, short films, ads related to the prototype	Developing marketing strategies, taking responsibility, persuasion and communication, competitive thinking, and adapting to different areas	For each group: A computer For each participant: An engineering design notebook, at least two colored pencils