ORIGINAL ARTICLE

Professional Learning Community (PLC) in STEAM Education: A Hands-On Workshops Sample¶

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***Abstract**: STEAM education puts professional learning communities on the agenda by requiring teacher collaboration along with disciplinary integrity. In this study, a professional learning community in STEAM education was investigated by observing 49 teachers from different disciplines working in different districts during 16 weeks of interdisciplinary training and their practice with students. Teachers' perceptions of skills teaching self-efficacy, design self-efficacy and perceptions of interdisciplinary teaching were assessed using pre-post tests. The research concluded that the STEAM professional learning community study positively improved teachers' perceptions of skill teaching self-efficacy and interdisciplinary teaching, but was not sufficient to develop design self-efficacy. It was found that teachers' views of practice were positive and that interdisciplinary collaboration contributed to this. In light of the research findings, it was suggested that the use of professional learning communities in STEAM education may be an effective example of the interdisciplinary functioning of hands-on workshops.*

Science Insights Education Frontiers 2024; 20(1):3149-3172.
DOI: 10.15354/sief.24.or496

How to Cite: Gülhan, F. (2024). Professional learning community (PLC) in STEAM education: A hands-on workshops sample. Science Insights Education Frontiers, 20(1):3149-3172.

***Keywords:** STEAM, STEM, Interdisciplinary, Professional Learning Community, Teacher Training, Hands-On, Workshop*

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***Conflict of Interests**: None*

¶: A part of this research was presented as an oral presentation at the 1st Istanbul School Administrators Congress (17-18 May 2023, Istanbul).

***Note**: Permission was obtained from the Istanbul Provincial Directorate of National Education with E-59090411-20-47554064 coded document to research these studies.*

Introduction

THE interdisciplinary nature of STEAM education brings teachers together as a professional learning community. For this purpose, STEAM education, professional learning communities and studies that combine the two concepts were reviewed. From the applications in the literature, the possible reflections on the applications in the hands-on workshops were explored.

STEM/STEAM Education

Interdisciplinary approaches enable the establishment of new connections and a creative perspective by providing a holistic approach to problems (Klein, 2005; Lederman & Niess, 1997; Yıldırım, 1996). STEM (Science, Technology, Engineering, Mathematics) education has become a highly regarded approach among interdisciplinary educational approaches worldwide and is frequently discussed as a research topic in education (Arslan & Arastaman, 2021; Bybee, 2013; Freeman, Marginson, & Tytler, 2019; Schomer & Hammond, 2020). According to Beers (2012), STEM education includes the 4Cs (critical thinking, creativity, communication and collaboration) skills that are essential for the 21st century.

With the addition of A (art) to related fields under the name of STEAM, STEM education has gained a structure in which creativity comes to light even more (Bequette & Bequette, 2012; Lewis, 2015; Watson & Watson, 2013; Wynn & Harris, 2012). STEAM, as an expanded concept of STEM, involves the creation of a new curriculum by merging more than one subject (Kwon, Nam, & Lee, 2011). In this respect, STEAM represents a more holistic model of education than STEM (Huser et al., 2020). Due to its multidimensional nature, STEAM education requires the collaboration of teachers from different fields and with different experiences, as well as emphasising the collaborative work of students.

Professional Learning Community (PLC)

Learning communities are social entities created by involving colleagues, students and professionals in a way that allows each member to learn from each other (Glaze-Crampes, 2020). Professional learning communities; it is defined as an environment that promotes professional development, collaboration and innovation among teachers (Brown, Horn, & King, 2018). The success of these applications; it shows that learning and teaching starts with the students, and the role of the teacher is to facilitate learning (Phusavat et al., 2018).

Although originally developed for the business world, PLCs were adopted by educational reformers as a component of the teaching profession in the mid-1990s (Irish, 2016). Educators and administrators, Richard DuFour & Mike Schmoker, pioneered change in the education field with the learning communities they created (Brown et al., 2018). Teachers working in strong learning communities have been found to be more satisfied with their careers and are successful educators who stay in teaching long enough (Fulton & Britton, 2011). Teachers who participate in professional learning community practices have been found to improve in the areas of curriculum, classroom management, learning, teacher role, and learning to teach (Kareemee et al., 2019).

Internationally, PLC practices are referred to in different ways. Lesson study in Japan, lesson group and research group in Shanghai, "teach less learn more" model in Singapore, problem solving group in Finland (problem solving group) (Wetwiriyasakun et al., 2021). Ansawi & Pang (2017) found that perceptions of professional learning communities were positively and highly correlated with lesson study. Lesson study is seen as a way to facilitate the practice of professional learning communities (Chichibu & Kihara, 2013).

In school practice it can be focused on these four points: planning, data collection, intervention and enrichment stages (Cansoy & Parlar, 2017). Altun (2020) found that teachers are motivated to develop, their self-awareness and their ability to collaborate develop in the study in which he examined the professional learning communities in two schools in action research. Aykan & Yıldırım (2021) reported that science teachers' pedagogical knowledge and content knowledge improved in their research in which they integrated the lesson study model into distance STEM education.

Researches that Brings the STEM/STEAM Education and Professional Learning Communities (Plcs) Together

Communities of practice in STEM are a critical factor required by the interdisciplinary nature of the field (Han, Kelley, Mentzer, & Knowles, 2021). STEM/STEAM requires teachers from different disciplines to collaborate, which brings PLCs to the forefront (Blankenship, 2015; Bush et al., 2016; Irish, 2016; Öztekin, 2019). In STEM collaborative applications, team size, instructional goals, and the structure of collaboration between teachers have a significant impact on interdisciplinary success (Wang et al., 2020). In a systematic review of research on STEM communities of practice, Han et al. (2021) found that supporting collaborative learning and context-based learning contributes to student learning by increasing STEM teachers' collaboration, teaching skills and self-efficacy.

Studies on the close relationship between STEM/STEAM education and professional learning communities can be founded in the literature (Fulton & Britton, 2011; Glaze-Crampes (2020). Models developed for the combination of PLC and STEM are available in the literature (Kezar & Gehrke, 2017; Richmond et al., 2017).

The studies were conducted to emphasise the teacher collaboration in PLC applications: STEM professional development workshop (Khumwong et al., 2017; Phusavat et al., 2018; Woodruff, 2021), sustainable PLC system (Phusavat et al., 2017), out-of-school STEM (Kelley & Williams, 2013; Santaolalla et al., 2020; Suriel et al., 2018; Swanson Hoyle, 2017; Swanson, 2018), STEM in the preschool period (Brenneman, Lange & Nayfeld, 2019), online PLC STEM education (Kareemee et al., 2019), STEAM practices (Boice et al., 2021; Cook, Bush, Cox Jr & Edelen, 2020; Pollard, 2019), design and technology education (Vossen, Henze, De Vries & Van Driel, 2020), problem solving to socioscientific issues (Ekici et al., 2018; Thana, Siripun & Yuenyong, 2018).

Similar to professional learning communities, the number of applications of the model, which is called course research, in interdisciplinary curricula such as STEM is much lower in the literature (Gülhan, 2021a; Holden & Fotou, 2021). Therefore, there is a need for research that combines the concepts of STEM/STEAM education and professional learning communities/course research.

A Hands-On Workshops Sample: Design Skill Workshops (DSW)

Design Skill Workshops is an application included in the 2023 Vision Document of the Ministry of National Education of the Republic of Turkey. In this document, it is described as "an area to be established in all schools for the development of children's interests, talents and dispositions" (MoNE, 2018, p. 24). The design skills workshops are similar to the maker workshops in the global examples, but they are separated from the other global examples by the addition of sports and living spaces (Mısırlı, 2021). STEAM education encompasses many disciplines, it can gather all areas of science, arts, sports, culture and life in DSW under one roof. This brings to mind the necessity of applying interdisciplinary approaches in order to shape DSW with an educational structure.

In the survey conducted among school stakeholders in Istanbul regarding their expectations of DSW, it was found that DSW was viewed positively and hope, but teachers were the group most worried about the risks that DSW might pose (Gülhan, 2021b). Considering that teachers are the key educational element, it can be concluded that one of the most important steps is teacher education.

In DSW, it is considered as the ideal element for collaborative and interdisciplinary teaching and where the most valuable equipment in its content is activities rather than space (Istanbul Provincial Directorate of National Education-IstMEM, Design skill workshops-application guide and interdisciplinary activity suggestions booklet, 2021). In this regard, studies have been conducted to transform DSW into a STEAM and professional learning community application specific to Turkey. The activities of the Istanbul DSW Academy, in which teachers from different branches and working in different districts apply by application, and the trainers are teachers with workshop experience, that has lasted throughout an educational period, were the subject of this research in 2021-2022 fall session.

In this research, the concepts of STEAM education and professional learning communities in the international literature were brought together under the roof of DSW in the sample of Turkey, and it aimed to provide an example of how to handle and maintain DSW with an interdisciplinary approach. For this purpose, the following questions were investigated in the research:

1. What is the effect of a STEAM professional learning community (PLC), on teachers' perceptions of their self-efficacy for teaching skills?
2. What is the effect of a STEAM professional learning community (PLC), on teachers' design self-efficacy?
3. What is the effect of a STEAM professional learning community (PLC), on teachers' perceptions of interdisciplinary teaching?
4. What are the opinions of the teachers who participated in the implementations, of the STEAM professional learning community (PLC)?

Methodology

The mixed method was used in this study. The mixed method has been; it is described as "a middle ground between empirical quantitative strategies and natural-qualitative strategies" (Patton, 2014). While the pretest-posttest single-group experimental design was used in the quantitative part of the research, the case study was used in the qualitative part. The findings obtained from the quantitative tests were supported by the findings obtained from the open-ended questions. Permission was obtained from the Istanbul Provincial Directorate of National Education to conduct these studies.

Participants

Table 1. Demographic Information of the Participants of the Research.

Gender (f)		Where They Work (f)		Professional Sceneries (f)		Educational Situations (f)		Branches (f)	
Woman	2	European Side	4	1-5 year	5	License	6	Primary school teacher	12
Man	7	Anatolian Side	5	6-10 year	15	Master	3	Technology-design	9
				11-20 year	20			Pre-school teacher	7
				20 above	9			Science	3
								Information technologies	3
								Mathematics	3
								English language	3
								Guidance and psychological counseling	3
								Special education	2
								Physical education	1
								Visual arts	1
								Music	1
								Geography	1

Maximum variation sampling, which is one of the purposive sampling methods, was used in the study. The aim of maximum diversity sampling is to reflect the diversity of individuals in a relatively small sample at the maximum level and to investigate the existence of common or shared phenomena in diverse situations (Yıldırım & Şimşek, 2008). In the research, in order to reach teachers from different branches working in different districts, applications were received via the link created through Google Forms. The application form asked about the district-school, the year of professional seniority, the branch, whether they had conducted workshops in their schools, the training they had previously received and the reasons for applying for this training. By examining the answers, teachers with different characteristics were selected. The study group of the research consisted of 49 teachers selected from among the teachers who applied to the Academy.

As can be seen in **Table 1**, 32 (65.31%) of the 49 participants are women. The professional seniority of most of the participants (40.82%) is between 11-20 years. Most of the participants (73.47%) are undergraduate graduates. Looking at the distribution by branches, it is seen that primary school teachers (24.49%), technology design teachers (18.37%) and pre-school teachers (14.28%) are in the majority, respectively.

The interview questions, which are the qualitative part of the research, were applied to 6 teachers selected from the study group with maximum diversity sampling. The teachers to whom the interview questions were applied; they are teachers who represent a wide spectrum in terms of group, gender, branch and professional seniority. The teachers' answers of the teachers were evaluated by coding them as T1, T2, T3 etc. The descriptive characteristics of the interviewed teachers are as follows: T1 coded teacher is a female primary teacher with 15 years of seniority. T2 coded teacher is a female physical education teacher with 8 years of seniority and a master's degree. T3 coded teacher is a male information technology teacher with 7 years of seniority. T4 coded teacher is a female primary teacher with 21 years of seniority. T5 coded teacher is a male primary teacher with 25 years of seniority. T6 coded teacher is a female pre-school teacher with 14 years seniority and a master's degree. Interviews were conducted with these teachers, who had mixed characteristics and were selected with maximum diversity sampling.

Data Collection Tools

The characteristics of the data collection tools used in the research are explained under the headings.

Perception of Skill Teaching Efficiency Test

The Cronbach Alpha reliability coefficient of the scale, which was developed by Çelik and Çetin (2020) and whose validity and reliability studies were conducted, was found to be 0.95 and it was determined that the scale was suitable in terms of fit indices. Sub-dimensions of the scale; It covers 21st century skills consisting of collaboration (10 items), communication (8 items), creativity (7 items), problem solving (4 items) and critical thinking (3 items). The 5-point Likert-type test, consisting of 32 items, aims to measure teachers' perceptions of competence about the teaching of the specified skills.

Design Self-Efficacy Scale

The scale developed by Beeftink et al.d (2012) was adapted into Turkish by Atabek (2020), and it was determined that the Cronbach Alpha reliability coefficient of the scale was 0.87 and it had adequate psychometric properties. The 5-point Likert-type test, which consists of 8 items, aims to measure the perception of self-efficacy regarding the realisation of the design.

Perception of Interdisciplinary Teaching Test

The Turkish adaptation of the scale developed by Bayer (2009) was conducted by Karahan et al. (2017). The researchers found that the Cronbach Alpha reliability coefficient of the scale was 0.71 and the fit indices were significant. The 5-point Likert-type test, which consists of 16 items, aims to measure teachers' perceptions of interdisciplinary teaching.

The Interview Form for Evaluation of Implementations

The interview form by the researcher includes 6 open-ended questions. The first three of the questions are questions that examine the development of skills teaching efficacy, design self-efficacy and perceptions of interdisciplinary teaching in support of the 3 questionnaires used in the research. The other three questions are designed to establish their views on teaching. These are questions about the practice of course research, about their views on working collaboratively with their colleagues, and about expressing the positive and negative aspects of education and its permanence. The questions were administered in writing to 6 teachers selected with maximum diversity sampling from the group and subjected to descriptive analysis.

Implementation of Research

The aim of this training is for each teacher to have an idea about each type of workshop, so that a holistic perspective can be created for the lesson plans to be developed as a professional learning community.

The Istanbul Design Skill Workshops (DSW) Academy, where the research was carried out, it consists of the sections of discovery, production and dissemination covering an education period. The discovery period, which started in September 2021, ended in December 2021, after which the production period continued until February 2021. The dissemination period ended in March 2022 and the final tests were carried out. During the dissemination period, which began after the end of the research, teachers attended school-based training sessions and implemented the practices with their colleagues.

During the exploratory phase, teachers were given practical training in workshop types. As all those working as trainers are teachers, a teacher-to-teacher exchange of experience was realised during the discovery phase. The trainers are teachers who have experienced and practised each type of workshop, coordinated by a specialist in interdisciplinary approaches (STEM/STEAM educator). During the 9-week discovery phase (one day per week), teachers participated in workshops. They carried out practical activities by recognising the types of workshops. Istanbul DSW Academy trainings were held once a week in two centres on the European and Anatolian sides, the same training was given to both groups.

During the production period, the teachers prepared interdisciplinary activity plans with groups of teachers from different branches, which they formed optionally. They applied the interdisciplinary activity plans they prepared with the students in the workshop environments. They revised and finalised their plans by discussing them. This study was transformed into a booklet and digitally published by the Istanbul Provincial Directorate of Na-

Table 2. Implementation Schedule and Contents.

Research Step	Period (Week)	Implementation Step
DISCOVERY period in which hands-on work is done in workshop types	1	Application of pre-tests and start of research
	2	STEM Workshop
	3	Software-Design Workshop
	4	Nature and Animal Care Workshop
	5	Drama and Critical Thinking Workshop
	6	Wood-Metal Workshop
	7	Life Skills Workshop
	8	Indoor Sports and Saloon Sports
	9	Music Workshop
	10	Visual Arts Workshop
PRODUCTION period, in which activity plans are developed and implemented with students with the lesson study model	11	Formation and planning of working groups
	12	Discussions on plans
	13	Practice with students
	14	Revision of plans
	15	Finalization of the production period
	16	Making plans for workshop types
DISSEMINATION period, of trainers for teachers	During The month	Realization of school-based teacher training and implementation of the post-tests

tional Education (IstMEM-DSW Examples of Interdisciplinary Activities Teacher's Booklet, 2022).

In the third and final stage, called dissemination, the teachers who had completed the training at the DSW Academy in Istanbul started to take part in in-service teacher training. To do this, they first identified the type of workshop they would train, and then created teacher training activity plans together with the teachers who had chosen the same type of workshop. They then carried out school-based training for teachers working in schools with workshops. Similar to the training they had received themselves, they provided their colleagues with one-day training sessions in which the workshop types were introduced and practical activities were carried out. The whole process is summarised in **Table 2**.

Table 3. Normality Analysis of Data.

	Test	Statistics	df	Sig
Perception of Skills Teaching Efficiency	Pre test	0.584	49	0.000
	Post test	0.707	49	0.000
Design Self-Efficacy	Pre test	0.933	49	0.008
	Post test	0.905	49	0.001
Perception of Interdisciplinary Teaching	Pre test	0.867	49	0.000
	Post test	0.967	49	0.176

Analysis of Data

In order to analyse the data obtained from the data collection tools used in the research, it was first examined whether they showed a normal distribution (**Table 3**).

Since the Shapiro-Wilks test is recommended for normality analysis in case the group size is less than 50 (Büyüköztürk, 2015), the analysis was performed with the related test. Since the p value of the tests was less than 0.05, it was determined that the scores did not show normal distribution (except for the last application of the perception test for interdisciplinary teaching), and analysis was performed with the non-parametric Wilcoxon signed-rank test.

Descriptive analysis was used to evaluate the interview questions in a qualitative research study. Data analysis steps in qualitative research; it consists of the steps of organising raw data, reading all of the data, coding the data, creating themes or descriptions, linking themes or descriptions, interpreting the meaning of themes or descriptions (Creswell, 2014). The data was subjected to descriptive analysis.

Findings

In this section, findings were obtained from the data obtained with the help of data collection tools and presented.

Findings Regarding Perception of Skills Teaching Efficiency

Table 4. Findings Regarding Perception of Skills Teaching Efficiency.

Skills Teaching Efficiency Perception	Posttest-pretest scores	N	Average rank	Total rank	z	p
Collaboration	Negative ranks	7	140.64	1020.50	-30.895*	0.000
	Positive ranks	31	200.60	6380.50		
	Equal	11				
Communication	Negative ranks	8	230.31	1860.50	-30.021*	0.003
	Positive ranks	32	190.80	6330.50		
	Equal	9				
Creativity	Negative ranks	10	150.70	1570.00	-20.008*	0.045
	Positive ranks	22	160.86	3710.00		
	Equal	17				
Problem solving	Negative ranks	13	130.85	1800.00	-20.232*	0.026
	Positive ranks	22	200.45	4500.00		
	Equal	14				
Critical thinking	Negative ranks	6	100.75	640.50	-30.331*	0.001
	Positive ranks	23	160.11	3700.50		
	Equal	20				
Perception of Skills Teaching Efficiency	Negative ranks	12	160.71	2000.50	-30.718*	0.000
	Positive ranks	34	250.90	8800.50		
	Equal	3				

**Based on negative ranks*

There is a significant difference between the skill teaching proficiency perception scores before and after the application ($z = 3,718$, $p < 0.05$). Since the observed difference is in favour of the post-test, it can be stated that the application has a positive effect on teachers' perceptions of skill teaching proficiency.

When the scores of the sub-dimensions of perception of competence in skill teaching before and after the application are examined, it is seen that there is a significant difference in each of them ($p < 0.05$). Since the observed difference is in favour of the post-test, it can be stated that the application has a positive effect on all sub-dimensions of teachers' skill teaching competence perceptions (**Table 4**).

Findings Regarding Design Self-Efficacy

There is no significant difference between the design self-efficacy scores before and after the application ($z = 1,461$, $p > 0.05$). Although there was an increase in the positive ranks in favour of the post-test, this difference was not significant, and it was found that the application was not effective in improving the design self-efficacy of the teachers (**Table 5**).

Table 5. Findings Regarding Design Self-Efficacy.

	Posttest-pretest scores	N	Average rank	Total rank	z	p
Design Self-Efficacy	Negative ranks	16	160.88	2700.00	-10.461*	0.144
	Positive ranks	22	210.41	4710.00		
	Equal	11				
	Total	49				

**Based on negative ranks*

Table 6. Findings Regarding Perception of Interdisciplinary Teaching.

	Posttest-pretest scores	N	Average rank	Total rank	z	p
Perception of Interdisciplinary Teaching	Negative ranks	10	170.45	1740.50	-40.361*	0.000
	Positive ranks	39	260.94	10500.50		
	Equal	0				
	Total	49				

**Based on negative ranks*

Findings Regarding Perception of Interdisciplinary Teaching

There is a significant difference between the perception scores of interdisciplinary teaching before and after the application ($z = 4.361$, $p < 0.05$). Since the observed difference is in favour of the post-test, it can be stated that the application has a positive effect on teachers' perceptions of interdisciplinary teaching (**Table 6**).

Findings Obtained from the Interview Questions for the Evaluation of Implementations

The answers given in the interview with 6 teachers among the study group were analyzed descriptively, coded and themes were created. It is presented with direct quotations and support.

Findings of the answers to the questions: “What can be done to teach students 21st century skills? What do you think the DSW Academy training process adds to you in terms of skill teaching?”

Among the 21st century skills of teachers, it was seen that the components of collaboration (f = 3) and creativity (f = 2) were most emphasised. The assessment that an interdisciplinary approach and teaching based on applied activities is a 21st century necessity was made by all interviewed teachers (f=6). As an example, the answer of the teacher coded T6, who emphasised the issues of collaborative work and creativity, is given below:

> *“I think that in the DSW Academy training, our individual achievements, our creativity motivation and collaborative work are given great importance.” (T6 coded teacher’s response)*

Findings of the answers to the questions: “How would you rate yourself about designing? What do you think the DSW Academy training process adds to your design skills?”

Some of the teachers stated that they think of designing as a lesson plan or activity design (f = 3) rather than designing products. There are also teachers who answered by evaluating design as an interdisciplinary field (f = 3). Below is the answer of the teacher coded T5 and T3 that illustrates this idea:

> *“I can say that the interdisciplinary relationship has opened my horizons. I create and implement a design for each lesson every week.” (T5 coded teacher’s response)*

> *“Designing has always been in my life, but I was thinking about only one field. I have seen that it has a great contribution to my design in different fields with DSW Academy and it is related.” (T3 coded teacher’s response)*

As can be seen from the answers, it was interpreted that DSW Academy studies are effective in the formation of interdisciplinary design ideas. In order to exemplify this thought, the answer of the T4 coded teacher was given:

> *"I can say that the DSW Academy education opened a different window for me, not in terms of design skills, but in terms of why I made the design and how I would apply it." (T4 coded teacher's response)*

Findings of the answers to the questions: "What do you think about interdisciplinary teaching? What do you think the interdisciplinary practices in the DSW Academy education process add to you?"

The teachers stated that their interest in the interdisciplinary approach increased and they started to do research (f = 3), they witnessed the benefits to the students (f = 2), and the contribution of collaborating with their colleagues (f = 1). Below is the response of the T6 coded teacher, who considers interdisciplinary approaches as a collaboration with colleagues:

> *"During the DSW Academy process, I saw that we were able to create a joint product by agreeing with my friend in an area that seemed relatively far away from my field. The coming together of different disciplines has created a very valuable situation to combine forces in a way." (T6 coded teacher's response)*

Findings of the answers to the questions: "What did you encounter when you carried out the interdisciplinary activities in the lesson study practice you did with your groups? What were the positive and negative aspects?"

The interviewed teachers stated that positive contributions were made in the planning part (f = 3), the students' approaches during the application were positive (f = 1), and the low level of commitment of the group members might negatively affect the application (f = 1). As an example, the answer of T1 coded teacher is given:

> *"I can say that I had a little difficulty. I saw myself getting too far away from making lesson plans. It was great to have our friends from different branches with us. Where we had difficulties while integrating them into the lessons, their ideas came into play and our lesson plans became whole." (T1 coded teacher's response)*

Findings of the answers to the questions: "How did collaborating with your colleagues make you think? What were the positive and negative aspects?"

It was observed that the teachers interviewed gave positive evaluations in terms of sharing experiences (f = 3), working towards a common goal (f = 2) and enriching their perspectives (f = 1). The answers of T2 coded teacher who exemplify the situation are given:

> *"As someone who has always believed in the importance and power of collaboration, I can say that it is very enjoyable. In particular, different ideas, thoughts, opinions and suggestions allowed my perspective to be enriched. I didn't feel any negative side of it." (T2 coded teacher's response)*

Findings of the answers to the questions: "What were the positive and negative aspects of DSW Academy training? Do you continue to apply the knowledge and skills you acquired in training?"

There are teachers who evaluated the positive aspects of DSW Academy education as stimulating (f = 2) and emphasized the importance of being practical (f = 2). The answer of the teacher coded T6, which sets an example for these answers, is given below:

> *"After I got the logic in my head and assimilated it, it created a very convenient and easy-to-apply learning style theme for me. In addition to applying the knowledge and skills I gained in education in my classroom, I also give ideas and feedback to my colleagues around me." (T6 coded teacher's response)*

As the negative aspects of DSW Academy education, there were teachers who stated that the discovery period in which the workshop lessons were held should be longer (f = 3) and that there were deficiencies in the preparation of schools and teachers for this system (f = 1). The answer of the T3 coded teacher is given as an example:

> *"DSW Academy is more application and product oriented than theory. When designing something, I examine whether it is related to which achievement in which lesson is addressed. I have*

> *expertise in one area, but I add other areas to my teaching as much as possible." (T3 coded teacher's response)*

There were teachers who stated that they had plans to work in collaboration with their colleagues (f = 3) and that they were trying to establish a workshop (f = 1) to apply the knowledge and skills they had acquired in the DSW Academy. The answer of T2 coded teacher summarizing these ideas is given below:

> *"I share it with my other branch friends, and while I am preparing my annual plan for the next year, I have the idea of cooperating with my friends from different disciplines by adding interdisciplinary activities to my plan." (T2 coded teacher's response)*

Conclusion and Discussion

In this research, the concepts of STEAM education and professional learning communities (PLC) were brought together under the roof of DSW in the sample of Turkey, and the implementations were studied.

The following results were obtained with the application made in the research: The STEAM professional learning community, improved teachers' perceptions of skill teaching self-efficacy and all its sub-dimensions in a positive way. The skills teaching questionnaire and the interview questions were found to be mutually supportive. The fact that the most emphasised 21st century skills component in the answers given to the interview questions was collaboration, was supported by the fact that it was the most developed dimension (z=3.895, p=.00) in the pre-post survey.

The STEAM professional learning community did not make a significant difference in improving teachers' design self-efficacy and was ineffective. It can be said that the design skills questionnaire and the data from the interview question are mutually supportive. The fact that there was no significant difference between the pre-post tests in the findings of the questionnaire was confirmed by the teachers' statements that their design skills did not develop significantly. However, the teachers stated that their interdisciplinary design thinking and design skills in creating lesson plans and activities had improved.

The STEAM professional learning community has improved teachers' perceptions of interdisciplinary teaching in a positive way. The positive result obtained from the perception scale for interdisciplinary teaching is also supported by the answers to the interview questions. Teachers expressed ideas about developing DSW Academy's interest in interdisciplinary approach, working collaboratively with colleagues and evaluating its positive reflections on students.

It was stated that positive contributions were made in the planning part of the course research practice made during the activity development process of DSW Academy, the students' approaches during the application were positive, and the low level of commitment of the group members could negatively affect the practice. Teachers were very positive about their collaboration with colleagues in terms of sharing experiences, working towards a common goal and enriching their perspectives. Teachers, who stated that the DSW Academy training was stimulating, that it was very important to be practical, and that the discovery period should be longer, also stated that they shared the knowledge and skills they acquired at the DSW Academy with their students and colleagues in the classroom.

The results obtained in this study are supported by research that indicating that professional learning community practices in STEM/STEAM education have positive effects on learning (Boice et al., 2021; Cook et al., 2020; Ekici et al., 2018; Fulton & Britton, 2011; Han et al., 2021; Kelley & Williams, 2013; Khumwong et al., 2017; Phusavat et al., 2017; Phusavat et al., 2018; Pollard, 2019; Suriel et al., 2018; Swanson, 2018; Swanson Hoyle, 2017; Thana et al., 2018; Vossen et al., 2020; Woodruff, 2021). When evaluating the use of the lesson study model in the production period, which is one of the application steps of the research, it can be associated with STEM education and lesson study. The studies in which STEM education plans are supported by the lesson study model also support this research with positive results (Aktürk, 2019; Aykan & Yıldırım, 2021; Lertdechapat & Faikhamta, 2021). Based on these results, it can be stated that lesson study and professional learning communities in STEM/STEAM education make positive contributions for teachers.

The development of teachers' perceptions of skills teaching self-efficacy shows the STEAM professional learning community studies are effective in achieving this goal. Furthermore, the development of all sub-dimensions of 21st century skills further strengthens this finding. Khumwong et al (2017) reached a conclusion that supports this study, stating that STEAM professional development workshops improve teachers' STEM teaching activities and that one of the most developed dimensions is the development of 21st century skills. Similarly there are studies that have concluded that STEM education practices improve teachers' STEM teaching self-efficacy (Arendall et al., 2018; Francis et al., 2018; Gardner, Glassmeyer & Wothy, 2019; Kelley et al., 2020; Kurtulan, 2021, Santaolalla et al., 2020). Dong et al. (2019) stated that teachers' STEM teaching self-efficacy, pedagogical design self-efficacy and peer support have a direct impact on STEM teaching participation; they found that the strongest predictor among them was teaching self-efficacy.

It is also noteworthy that the practices that were carried out on teachers' design self-efficacy were ineffective. Similarly, Kayalar (2018) stated that engineering design skills were not developed as a result of STEM education with prospective teachers. This finding was interpreted in a critical appraisal of the applications made in the research as meaning that studies were only carried out within the content of the STEM workshop on the development of design skills, and that the applications were generally carried out with more emphasis on interdisciplinary approaches to teaching skills.

In summary, this research concluded that the STEAM professional learning community study positively improved teachers' perceptions of skills teaching self-efficacy and interdisciplinary teaching, but was not sufficient to develop design self-efficacy. It was found that teachers' views of practice were positive and that interdisciplinary collaboration contributed to this. In the light of the research findings, the following suggestions were made:

In the study, the achievements of the students with the professional learning community (PLC) practice in STEAM education were not examined. Future research can investigate how teachers' professional development practices affect students.

As one of the limitations of the research, professional learning communities were considered as "people participating in the practice" and the organisational structure was neglected. Detailed and in-depth research, including the school's management structure, can be conducted in professional learning communities' researches on teachers in a particular school.

In this study, due to the interdisciplinary focus, small groups were formed with teachers from different branches. In other studies, the studies of group teachers from the same branch can also be examined.

The lesson study carried out during the production period, which is the second of the stages of the Istanbul DSW Academy applied in the research, was treated within the integrity of the research, but was not studied separately. In-depth studies can be conducted on the effectiveness of lesson study practices.

This study, which was carried out within the scope of DSW Academy, can be adapted to other educational approaches where interdisciplinarity and practice are at the forefront.

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Received: 14 July 2023
Revised: 07 August 2023
Accepted: 27 August 2023