Id: 1255097

Participatory Educational Research (PER)
Vol.10(3), pp. 247-265, May 2023
Available online at http://www.perjournal.com
ISSN: 2148-6123
http://dx.doi.org/10.17275/per.23.54.10.3

# The Impact of Technology-Supported Interdisciplinary Integration on Critical Thinking and Creativity: The Perspective of Pre-Service Teachers

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**Article history**

**Received:**
22.02.2023

**Received in revised form:**
20.03.2023

**Accepted:**
13.04.2023

**Key words:**
Technology education; interdisciplinary integration; critical thinking; creativity; pre-service teachers

In the present study it is aimed to investigate the pre-service science and mathematics teachers' opinions on the effect of technology-supported interdisciplinary activities on critical thinking and creativity. This study was designed as a case study, a qualitative research method. A total of 17 pre-service teachers were selected for the current study. Four questions were included in the survey to gauge pre-service teachers' opinions on the impact of technology-supported interdisciplinary integration on critical thinking and creativity. Research was undertaken to gather information from the relevant literature while formulating the questions. Due to the pandemic, the technology-supported interdisciplinary science and mathematics integration course was delivered via remote education. This research was carried out throughout the academic year 2020-2021. The data collection method was used as an online form for the participants. The online technology-supported interdisciplinary course application was completed during 25 hours of instruction. TUBITAK financed this course in the 2021/1 term under the project code 1129B372100437 as part of the 2237-A program. Content analysis was used to examine the data gathered from the open-ended question form. It was concluded that the pre-service teachers participating in the study generally had positive views about technology-supported interdisciplinary activities. Participants stated that in the student context, the activities increased students' interest in the lesson, enabled a holistic perspective, provided solutions to real-life problems, and improved their thinking skills. The responses received from the participants indicate that these activities have a positive effect on critical thinking skills in the context of both the student and the teacher.

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## Introduction

In recent years, interdisciplinary approach has taken the place of disciplinary teaching, in which different courses are taught separately from each other. The interdisciplinary approach is based on using different disciplines that make up the infrastructure of the curriculum together. Interdisciplinary way of working combines two or more different disciplines in a more complex manner. This method to practice allows for a more collaborative and integrated approach (Darbellay, 2014). Since education based on interdisciplinary relations is more suitable for the individual's natural learning process and way of perceiving the world, it is necessary to apply all disciplines so that education can be comprehended from every angle and with all its dimensions (Mialaret, 2010).

Interdisciplinary learning is a tool used to solve a problem or issue that cannot be solved with a single discipline (Dezure, 2000). It is known that the interdisciplinary approach contributes to the solving of complex problems and the development of high-level mental skills (Haring & Kelner, 2015; Michelsen, 2015). In addition, raising creative individuals who research, question, think critically and make decisions are also within the scope of the interdisciplinary approach (Brophy et al., 2008; Tyler-Wood et al., 2010).

Interdisciplinary relationships between mathematics and science are very important as mathematics is applied in diverse disciplines and these relationships lead to advancements across disciplines (National Research Council, 2013). Both mathematics and science educators need to consider the implications of this interdisciplinarity in terms of effective teaching and learning. Like many other countries, Turkey primary and secondary education curricula require teachers to enhance the synergy between these disciplines by application of mathematics to science or vice versa. Therefore, there is a clear need for teaching science and mathematics concepts using interdisciplinary approaches which provide students meaningful learning experiences (Canbazoğlu-Bilici et al., 2021).

The rapid development of science and technology in the 21st century has brought along a serious competition in global economy. To develop their economies, countries require entrepreneurial and creative individuals who possess critical thinking skills, who can find solutions to daily life problems and utilize technology well. Curricula should be created with an interdisciplinary approach train individuals to be able to adapt to the age by gaining 21$^{st}$ century skills such as creativity, critical thinking, leadership and scientific literacy etc. From this point of view, it is an undeniable fact that there is a need for individuals who can think freely, analytically, creatively and, above all, critically, in order to raise successful individuals in the future. Various environments should be provided for the teachers who will shape the future so that they can think critically, and their ideas should be given importance (Bardak & Karamustafaoglu, 2016a). From this point of view, in the present study it is aimed to investigate the pre-service science and mathematics teachers' opinions on the effect of interdisciplinary activities on critical thinking and creativity.

## *Theoretical Framework*

### *Critical thinking*

"Critical thinking is defined by an intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action." (Scriven & Paul, 1987). Similarly, The

World Economic Forum (2020) defined critical thinking as "Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems."

The World Economic Forum (2020) Future of Jobs Report highlighted the top skills which employers see as rising in prominence in the lead up to 2025. Accordingly, top eight skills are: 1) Analytical thinking and innovation, 2) active learning and learning strategies, 3) complex problem-solving, 4) critical thinking and analysis, 5) creativity, originality and initiative, 6) leadership and social influence, 7) technology use, monitoring and control, and 8) technology design and programming. This report revealed that critical thinking and creativity are two of the most important 21st century skills, and technologically literate individuals will be one step ahead in the business world soon.

In the 20th century, educators recognized critical thinking as one of the primary objectives of education since it is one of the most productive types of thinking. There are several cognitive and affective benefits in education to critical thinking. Cognitive aspects of critical thinking; analysis - synthesizing, assessing an argument, subject, or alternative point of view against legitimate criteria, drawing legitimate inferences, coming to reasoned conclusions based on legitimate data, forming interdisciplinary connections, and keeping an eye on one's thought processes. In this sense, making interdisciplinary connections is also a part of critical thinking (MoNE, 2015).

According to the findings of the 21st Century Student Profile (2011) research conducted by the Ministry of National Education (MoNE) with approximately 11000 teachers, most of the teachers stated that critical thinking is not sufficiently gained to the high school students. In order to overcome this problem, which will have a negative impact on the country's economy in the long run, students should be gained critical thinking skills at a young age. Therefore, teachers should give importance to develop their students' critical thinking skills through technology-enhanced interdisciplinary activities. Concordantly, studies revealed that interdisciplinary learning (Courtney, 2006) and technology-enhanced activities make a significant contribution to the individuals' critical thinking skills (Giraldo-Garcia et al., 2015; Gürsan et al., 2021).

*Creativity*

Creativity is defined as the ability to produce new and original ideas or products (Kanematsu & Barry, 2016). Creativity is one of the basic requirements of the 21$^{st}$ century (Partnership for 21$^{th}$ Century Skills, 2019) and of the higher order thinking skills (Heong et al., 2011). Creativity can be manifested in an article written about a subject, in a speech, in a play written, directed, and exhibited, in music composed, in the business world, in artistic fields such as painting, and in scientific exploration, ideas and research (Haladyna, 1997). There are different definitions to explain creativity in different fields. For example, in science and mathematics, creativity is defined as the ability to solve a given problem in a new way by employing knowledge, concepts, principles and thinking strategies (Kim et al., 2016). Six components are identified as essential for creativity: Enquiry, evaluation, ideation, imagination, innovation, and problem solving (Compton, 2007). Many educational approaches can be used to provide these six components. One of them is the interdisciplinary approach.

Interdisciplinary approaches and creativity have many connections. The interdisciplinary approach reduces imitation and promotes creativity. Ongoing research demonstrates that

interdisciplinarity best fosters students' active participation in wide critical and contextual thinking as well as problem solving (Fartushenko, 2011).

Bolden et al. (2010) underlined that teachers should foster creativity in their students. Eckhoff (2011) stated that pre-service teachers value creativity, but they do not know how to implement creativity education in the classroom. Teachers find it challenging to incorporate creativity into the classroom for a variety of reasons, including the belief that they lack knowledge, a sense of insecurity about the subject, the belief that one lesson will not be sufficient to apply these techniques, and the belief that the lessons about these techniques are few or insufficient during their undergraduate education (Bardak & Karamustafaoğlu, 2016b; Bardak & Karamustafaoğlu, 2016c).

Creativity is a perfect object of study which is eligible for interdisciplinary approach (Darbellay et al., 2017). Moreover, thanks to educational technologies, students can develop their creativity by using multimedia (Alkan, 2005). Considering that both technology and interdisciplinary teaching support creativity, it is thought that developing the creativity of pre-service teachers through technology-enhanced interdisciplinary activities will contribute to their future professional life and play an important role in the development of their students' creativity.

The following research questions were addressed to guide the present study:

(1) What are the pre-service teachers' perspectives on technology-supported interdisciplinary activities?
(2) What are the pre-service teachers' thoughts on the advantages of technology-supported interdisciplinary activities?
(3) What are the pre-service teachers' thoughts on the impact of technology-supported interdisciplinary activities on critical thinking and creativity?

## Method

### *Research design*

This study was designed as a case study, a qualitative research method. A case study is an in-depth study of a limited phenomenon. The most important feature of case studies is the limitation of the case (Merriam, 2013). The case considered in this study is the investigation of pre-service science and math teachers' opinions on the effect of technology-supported interdisciplinary integration on critical thinking and creativity. The case examined in the study was limited to the opinions of pre-service teachers who participated in activities related to technology-supported interdisciplinary integration.

### *Participants*

A total of 17 pre-service teachers (8 pre-service science teachers and 9 pre-service math teachers) were selected for the current study. Ten of the participants are in fourth grade, while the other seven are in third. Criterion sampling, one of the purposeful sampling approaches, was used to pick the participants. Criterion sampling examines all scenarios that fulfill a set of predetermined criteria (Patton, 2002). The following are the criteria for selecting research participants: To have completed and passed basic science and mathematics courses, to be a volunteer, and to be enrolled in one of the science or mathematics teaching departments.

***Research instruments and procedures***

The data for this study was gathered using an open-ended questionnaire designed by the researcher for teacher candidates. Four questions were included in the survey to gauge pre-service teachers' opinions on the impact of technology-supported interdisciplinary integration on critical thinking and creativity. Research was undertaken to gather information from the relevant literature while formulating the questions. In terms of content validity, the questions developed after the literature study were submitted to two experts on the subject, and their opinions were gathered.

The questions were finalized after necessary revisions were made based on the input received. The form's open-ended questions are:

- What are your positive and negative perspectives on technology-supported interdisciplinary integration activities?
- What are your opinions on the advantages of technology-supported interdisciplinary integration activities?
- What are your opinions on the impact of technology-supported interdisciplinary integration activities on critical thinking?
- What are your opinions on how technology-supported interdisciplinary integration activities affect creativity?

Due to the pandemic, the technology-supported interdisciplinary science and mathematics integration course was delivered via remote education. This research was carried out throughout the academic year 2020-2021. The data collection method was used as an online form for the participants. The online technology-supported interdisciplinary course application was completed during the course of 25 hours of instruction. The Scientific and Technological Research Council of Türkiye (TUBITAK) financed this course in the 2021/1 term under the project code 1129B372100437 as part of the 2237-A program. Table 1 shows the hourly implementation of the technology-supported interdisciplinary science and mathematics integration course.

Table 1. Hourly research design.

| **Hour** | Title | Content |
|---|---|---|
| 3 hours | Holograms with interdisciplinary science and math integration | The topic of holograms was discussed. The procedure of creating a sample hologram was described. Pre-service teachers used their imagination to create lesson plans utilizing holograms. |
| 2 hours | Integrating interdisciplinary research with a virtual tour | The virtual tour was described in detail. The virtual tour of the Kayseri Science Center in Turkey demonstrated how science and mathematics may be integrated. |
| 2 hours | Tangram's interdisciplinary integration | Tangram information was provided. Papers were used to make the Tangram. Pre-service teachers used their creativity to create several transdisciplinary shapes using the prepared tangram. |
| 4 hours | Mathematical modeling and interdisciplinary integration | Mathematical modeling information was provided. It explored how mathematical models relate to everyday life. Pre-service teachers developed interdisciplinary solutions by using mathematical models to think critically about everyday challenges in science and mathematics. |
| 3 hours | Integrating interdisciplinary research with augmented reality | The topic of augmented reality was discussed. The tools for augmented reality were discussed. The pre-service teachers used the Blipper program to showcase their creativity while also providing interdisciplinary integration between science and mathematics. |

| | | |
|---|---|---|
| 2 hours | Geogebra with interdisciplinary integration | Geogebra information was provided. Pre-service teachers used their imagination to create interdisciplinary applications with the Geogebra program. |
| 3 hours | Interdisciplinary integration applications based on simulation | The Algodoo program was discussed in detail. The Algodoo program was used to create sample apps. Using their imagination, pre-service teachers created interdisciplinary practices. |
| 3 hours | Argumentation-based STEM education with interdisciplinary integration | Pre-service teachers used critical thinking to create product designs to solve problems found in everyday life with argumentation-based STEM education. |
| 3 hours | Interdisciplinary integration with PhET simulations | Information about PhET simulations was given. The simulations of PhET are used as examples. Through PhET simulations, pre-service teachers engaged in interdisciplinary tasks by employing their creativity and critical thinking. |

Pre-service teachers have engaged in a variety of technology-supported interdisciplinary integration strategies, as shown in Table 1. Figure 1 depicts examples of hologram-related activities carried out by pre-service teachers. Figure 2 are examples of a simulation-related activities.

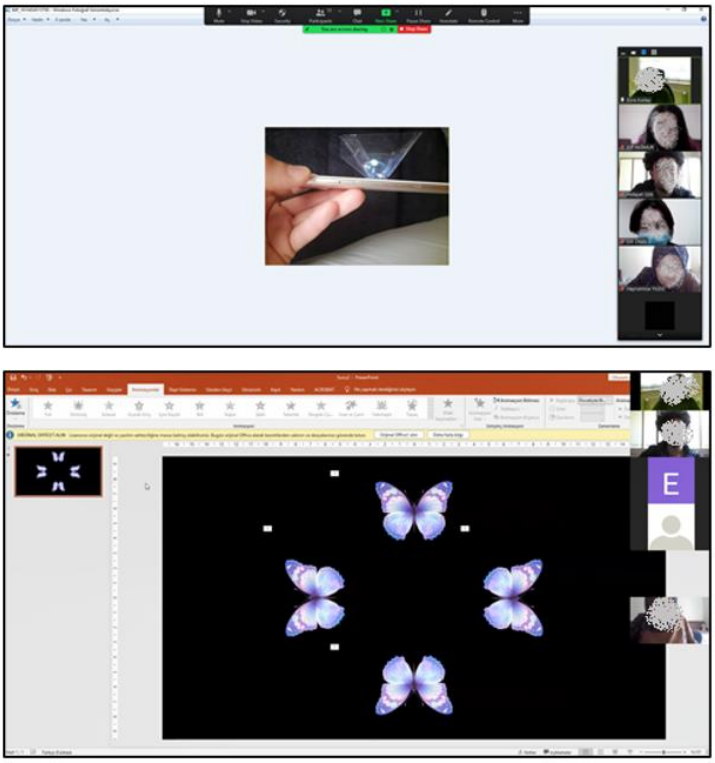

Figure 1. Hologram-related interdisciplinary activities

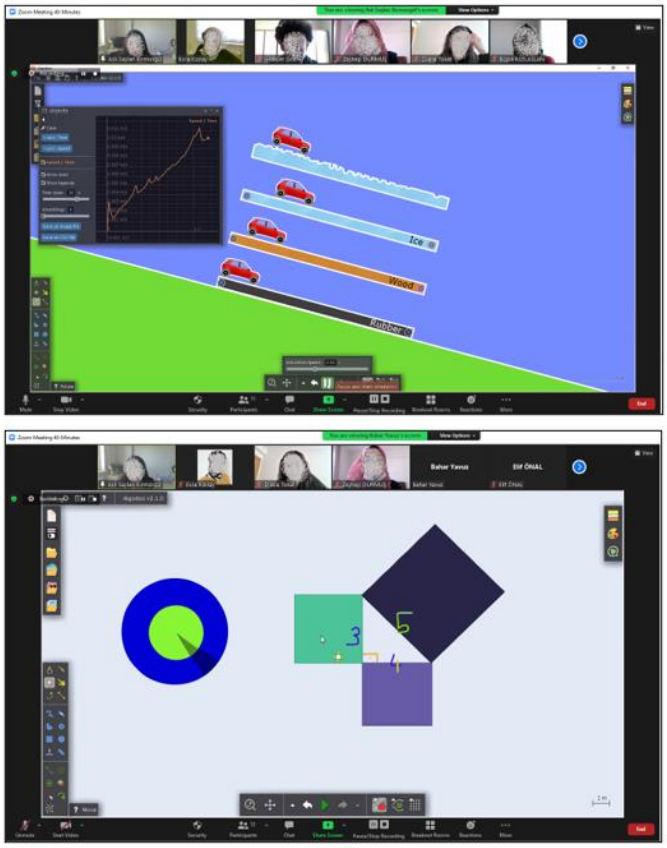


Figure 2. Simulation-related interdisciplinary activities

### *Data analysis*

Content analysis was used to examine the data gathered from the open-ended question form. The goal of content analysis is to distill and make sense of large amounts of qualitative data by focusing on its core coherence and meaning. In this study, inductive content analysis was preferred. Patterns, themes, and categories within the data are uncovered via inductive analysis (Patton, 2002). The dataset was coded with structural coding while doing inductive content analysis. In qualitative research, structural coding is used to construct categories from exploratory studies. The similarities, differences, and interactions between data sections are coded and categorized by study, especially in studies employing open-ended questionnaires (Saldana, 2019). The data in this study was first coded. The data was then categorized based on its similarities, differences, and relationships.

### *Trustworthiness and reliability*

Guba and Lincoln (1982) defined the criteria for trustworthiness in qualitative research as credibility, reliability, confirmability, and transferability. It is recommended to specify one or more of these four criteria to ensure trustworthiness in a qualitative study (Creswell, 2003). Purposive sampling method was used in this study to ensure external validity. In addition, detailed descriptions of the activities, practices and participants were made.

The percentage of agreement method developed by Miles and Huberman (1994) in qualitative investigations was used to assess the reliability of data analysis in this study. The percentage of reliability was calculated using the formula "Percent of agreement" =

[Agreement/(Agreement + Disagreement)]. This formula is intended to indicate the reliability of the analysis by demonstrating consistency between the analyses of the researchers who coded the data individually. In this case, two experts coded the collected data individually, and the amount of agreement between them was tested for consistency. The proportion of agreement between researchers was found to be 0.89 in the study. The data analysis was reliable based on this percentage of agreement.

## Findings

### *Positive and negative perspectives of pre-service teachers on technology-supported interdisciplinary integration activities*

The goal of the study's first sub-problem was to determine pre-service teachers' positive and negative perspectives on technology-supported interdisciplinary integration activities. Figure 3 shows the category, codes, and frequencies.

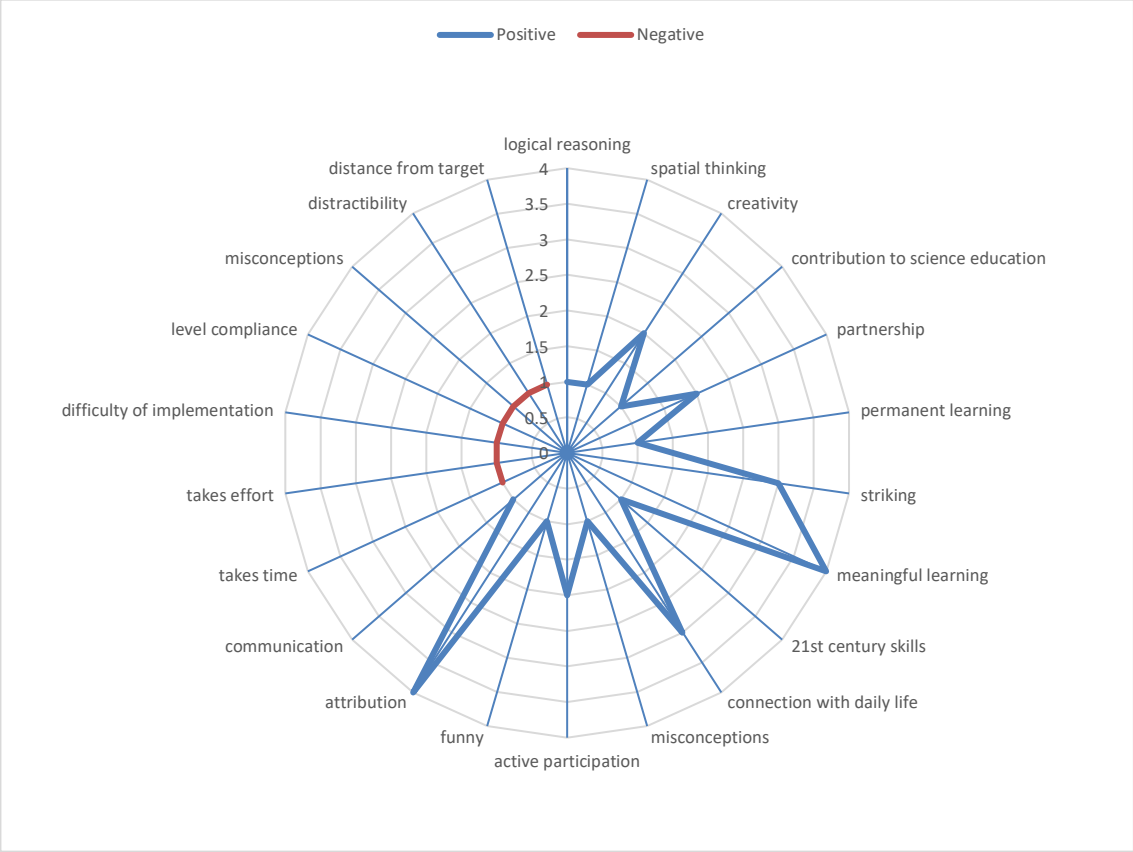


Figure 3. Positive and negative perspectives of pre-service teachers on technology-supported interdisciplinary integration activities

As seen in Figure 3, there are two categories: "positive", and "negative". Pre-service teachers expressed generally positive feelings about technology-supported interdisciplinary integration activities, according to the data. The most often expressed codes in the "positive" category were "meaningful learning" (n=4), "attribution" (n=4), "connection with daily life" (n=3), and "striking" (n=3). Other codes in this category include: "logical reasoning" (n=1), "spatial thinking" (n=1), "creativity" (n=2), "contribution to science education" (n=1), "partnership"

(n=2), "permanent learning" (n=1), "21st-century skills" (n=1), "misconceptions" (n=1), "active participation" (n=2), "funny" (n=1), and "communication" (n=1). When the data is evaluated, the pre-service teachers' judgments that technology-supported interdisciplinary integration activities have a positive effect on pre-service teachers' thinking skills and creativity stand out. "Takes time," "takes effort," "difficulty of implementation," "level compliance," "misconceptions," "distractibility," and "distance from target" were among the codes in the "negative" category. All codes in this category have a frequency of "1". The following are exhibitor quotes about categories and codes:

*"I believe that one of the benefits of interdisciplinary integration is that it provides students abilities such as permanent learning, logical reasoning, spatial thinking, creativity, cooperation, and etc..."* (Pre-service teacher 2)

*"If we don't know enough about the other field we'll be using with our field, we might produce certain misconceptions in the students..."* (Pre-service teacher 12)

### *Opinions of pre-service teachers on advantages of technology-supported interdisciplinary integration activities*

In the second sub-problem of the study, it was aimed to determine the opinions that define the pre-service teachers on advantages of technology-supported interdisciplinary integration activities. The categories, codes and frequencies related to this sub-problem are in Figure 4 that presented through tree map.

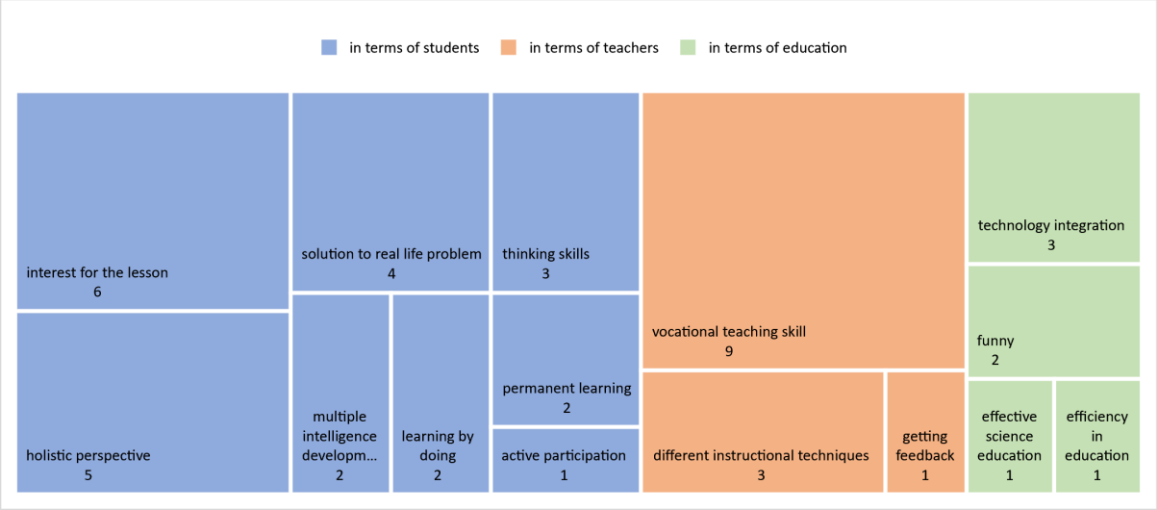


Figure 4. Opinions of pre-service teachers on advantages of technology-supported interdisciplinary integration activities

As seen in Figure 4, there are three categories: "in terms of students", "in terms of teachers", and "in terms of education". Pre-service teachers usually addressed the benefits of technology-supported interdisciplinary activities in terms of students, according to the data. The most often expressed codes in the "in terms of students" category were "interest for the lesson" (n=6), "holistic perspective" (n=5), "solution to real life problem" (n=4), and "thinking skills" (n=3). Other codes in this category include: "multiple intelligence development" (n=2), "active participation" (n=1), "learning by doing" (n=2), and "permanent learning" (n=2). "Vocational teaching skill" (n=9), "different instructional techniques" (n=3),

and "getting feedback" (n=1) were among the codes in the "in terms of teachers" category. "Technology integration" (n=3), "funny" (n=2), "effective science education" (n=1), and "efficiency in education" (n=1) were among the codes in the "in terms of education" category. The following are exhibitor quotes about categories and codes:

*"I believe that interdisciplinary activities assist students in a variety of ways. Students can learn by doing and experiencing as a result of these activities, and their learning will become more permanent as a result. Interdisciplinary integration activities, on the other hand, can draw students' attention and develop their problem-solving skills because they include real-life challenges."* (Pre-service teacher 2)

*"These activities, in my opinion, will extend students' horizons and help their spatial thinking, problem-solving, and creative thinking abilities. Furthermore, they will have a beneficial impact on teacher development because they are activities that encourage not only students, but also teacher candidates and teachers to continually generate new ideas and think…"* (Pre-service teacher 15)

### *Opinions of pre-service teachers on the impact of technology-supported interdisciplinary integration activities on critical thinking*

In the third sub-problem of the study, it was aimed to determine the opinions that define the pre-service teachers on impact of technology-supported interdisciplinary integration activities on critical thinking. The categories, codes and frequencies related to this sub-problem are in Figure 5.

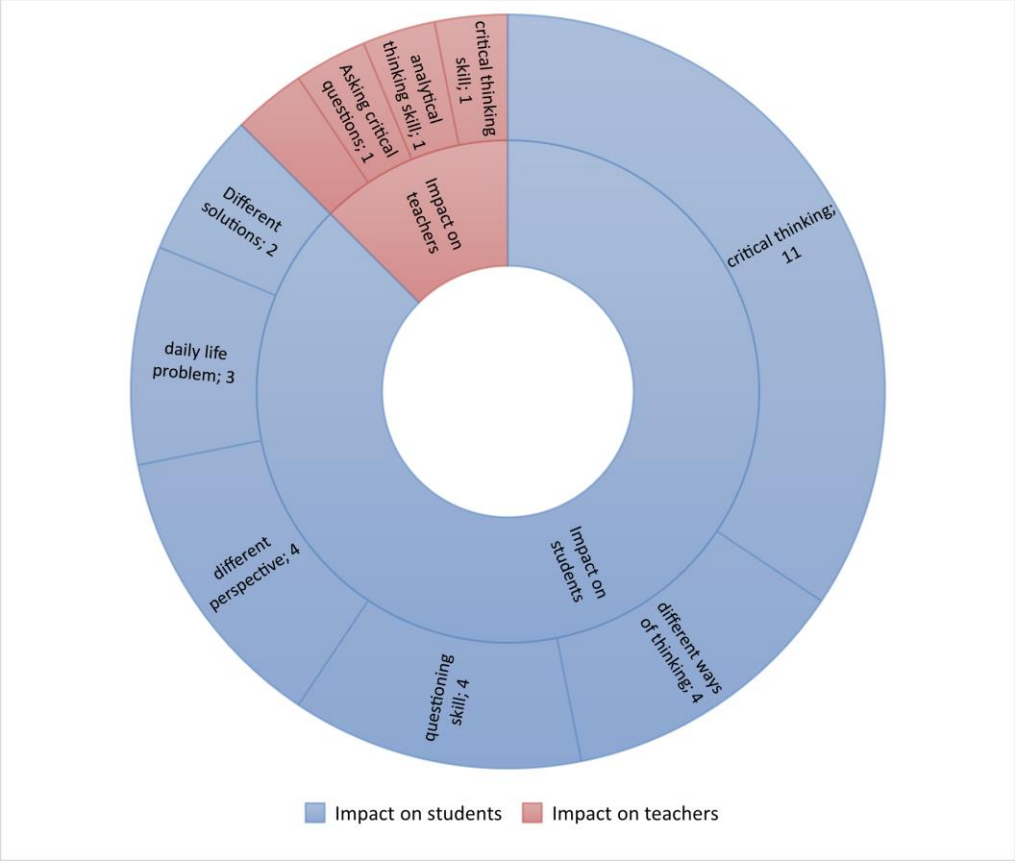


Figure 5. Opinions of pre-service teachers on impact of technology-supported interdisciplinary integration activities on critical thinking

As seen in Figure 5, there are two categories: "impact on students", and "impact on teachers". Pre-service teachers shared their thoughts on how technology-supported interdisciplinary activities affect students' critical thinking in general. The most often expressed code in the "impact on students" category was "critical thinking" (n=11). This data demonstrates that pre-service teachers believe that technology-supported interdisciplinary activities improve students' critical thinking abilities. "Critical thinking skill", "analytical thinking skill", "asking critical questions", and "scientific literate person" were among the codes in the "impact on teachers" category. The following are exhibitor quotes about categories and codes:

*" I believe that interdisciplinary integration activities are open to the structure of critical thinking in terms of arriving at a question's response from several options. Students are pushed to think in multiple ways through activities. Because it gives this, kids develop a more developed thinking rather than a monotonous point of view."* (Pre-service teacher 8)

*"These activities, in my opinion, contribute positively to critical thinking since they encourage students to consider many alternatives and weigh the benefits and drawbacks of each…"* (Pre-service teacher 15)

***Opinions of pre-service teachers on the impact of technology-supported interdisciplinary integration activities on creativity***

In the fourth sub-problem of the study, it was aimed to determine the opinions that define the pre-service teachers on impact of technology-supported interdisciplinary integration activities on creativity. The categories, codes and frequencies related to this sub-problem are in Figure 6.

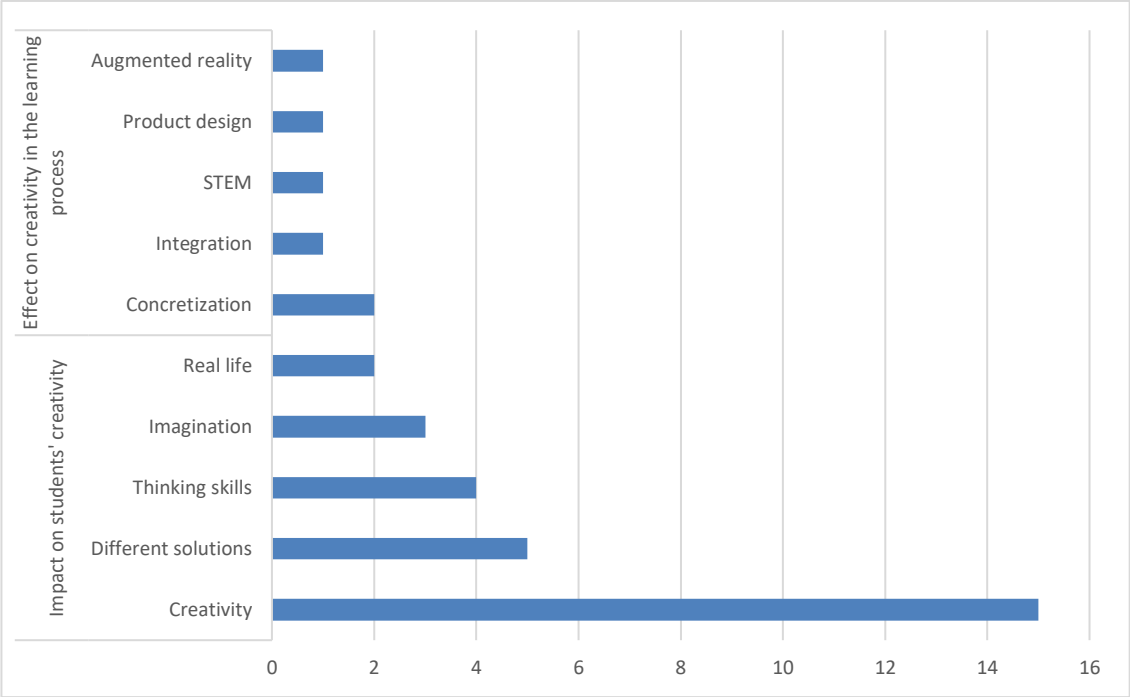


Figure 6. Opinions of pre-service teachers on impact of technology-supported interdisciplinary integration activities on creativity

As seen in Figure 6, there are two categories: "impact on students' creativity", and "effect on creativity in the learning process". Pre-service teachers shared their thoughts on how

technology-supported interdisciplinary activities affect students' creativity in general. The most often expressed code in the "impact on students' creativity" category was "creativity" (n=15). This data demonstrates that pre-service teachers believe that technology-supported interdisciplinary activities improve students' creativity abilities. "Creativity" (n=15), "different solutions" (n=5), "thinking skills" (n=4), "imagination" (n=3), and "real life" (n=2) were among the codes in the "impact on students' creativity" category. "Concretization" (n=2), "integration" (n=1), "STEM" (n=1), "product design" (n=1), and "augmented reality" (n=1) were among the codes in the "effect on creativity in the learning process" category. The following are exhibitor quotes about categories and codes:

*"It allows pupils to enhance their creativity through activities connected to interdisciplinary integration..."* (Pre-service teacher 1)

*"Activities that foster creative thinking include a structure that allows students to come up with solutions in a variety of ways. This demonstrates that the answer to a question can be found in a variety of ways, not just one…"* (Pre-service teacher 8)

## Discussion and Conclusion

The aim of this study was to determine the views of pre-service teachers about the advantages of technology-supported interdisciplinary activities and how they may affect critical thinking skills and creativity. In the light of the research hypotheses formed in this context, it was concluded that the pre-service teachers participating in the study generally had positive views about interdisciplinary activities. This finding of the study has also been reported in numerous studies in the literature (Erdogan & Ciftci, 2017; Karakus & Aslan, 2016; NSTA, 2006; Ozaydinli & Kilic, 2019; Suligoj et al., 2020). The participants attributed the reasons for their positive views on interdisciplinary activities to the fact that they enable meaningful learning, are associated with daily life, are more beneficial to themselves, and are effective. As de Greef et al. (2017) underlined in the literature, the interdisciplinary approach enables students to see things from a broad perspective, while in the study by Repko et al. (2016), it is stated that this approach method also helps students to relate the real world to their own education. In the context of higher education, this approach will contribute positively to the formation of creative environments and to the creation of a wide range of collective fields of study, as well as to innovative thinking skills (Gardiner, 2020). On the other hand, there are also those who have expressed negative opinions about interdisciplinary activities, especially, that it takes time, requires intensive work, is difficult to implement, misconceptions may occur, and there may be a case of deviation from the target. In studies reported in the literature, there are views stating that pre-service teachers do not have a good command of interdisciplinary activities (Cura & Ercan Yalman, 2019), and that therefore, they have certain disadvantages. This can be attributed to their inability to collaborate with and internalize different disciplines during their undergraduate education. Furthermore, it can be said that some of the negative aspects expressed by participants stem from the challenging task of designing instruction aimed at an interdisciplinary approach and of transferring between branches, as stated by Savard and Samson (2014). Zhang (2017) emphasizes the difficulties of interdisciplinary collaborations and activities, especially in higher education, and attributes this to the weakness of close relationships, support and feeling of trust while conducting interdisciplinary studies or activities. The fact that pre-service teachers mention the negative aspects of interdisciplinary activities is due to their lack of complete knowledge of the interdisciplinary concept and the lack of knowledge in practice, as stated by Song (2017). In parallel with this, Nikitina (2005) reports that pre-service teachers need to develop

their interdisciplinary perspectives. It can be said that this and similar situations lead to negative judgments against interdisciplinary activities and practices. It should be remembered that interdisciplinary integration challenges intellectual rigidity, and shows that holding one's position without understanding the benefits of humility or recognizing the strengths of other disciplines is a disadvantage. However, this does not devalue one's own domain knowledge, skills, or understanding. Interdisciplinary integration requires meticulousness and willingness, may require risk taking (Hamalosmanoğlu, 2022), and may require innovation generation by mixing ideas and the use of a common language for effective communication. Lyall et al. (2011) argue that interdisciplinarity approaches a subject from the perspective of a range of disciplines, and that the contributions of various disciplines are acknowledged and integrated to enable a holistic or systemic outcome: good interdisciplinary research is much greater than the sum of its parts. At the same time, we can see that lack of time is one of the limitations of the interdisciplinary teaching approach that is underlined in the literature (Sullivan, 2000; Suraco, 2006).

The quality that individuals should have at the first stage in interdisciplinary activities is the ability to make connections, that is, possessing integration skills. Moreover, they should also have qualities such as the ability to look at subjects from a different perspective, having enough basic knowledge about the subject area of each discipline, being willing to work collaboratively, and being able to fulfill their responsibilities (Budak Coşkun, 2009).

The second situation investigated in the research was concerned with determining pre-service teachers' views on the advantages of interdisciplinary activities. Within the scope of the research, the participants were asked to evaluate the conducted interdisciplinary activities in three contexts. The first of these is the context of the student. Participants stated that in the student context, the interdisciplinary activities increased students' interest in the lesson, enabled a holistic perspective, provided solutions to real-life problems, and improved their thinking skills. In this sense, making interdisciplinary connections is also a part of critical thinking (MoNE, 2015). The advantages expressed by the participants are similarly reported in the literature. For example, Birchinall (2013) states that the interdisciplinary approach increases students' interest, Cuervo (2018) and DiCamillo and Bailey (2016) state that interdisciplinary learning enables students to understand subjects or concepts more deeply, You (2017) reports that by broadening students' capacity to understand, the integration of knowledge provides enrichment by enabling them to examine events from more than one perspective, Hubert (2021) also states that this approach increases students' ability to see subjects from various perspectives as well as having a positive effect on student achievement, and Yarımca (2011) reports that it reflects daily life. It can be seen that the integration of disciplines is effective in the development of concepts and skills (Vasquez et al., 2013). In the context of the teacher, participants expressed the advantages of interdisciplinary activities as developing professional teaching skills and enabling the use of different teaching techniques. This finding is also similarly reported in the literature, in which it is stated that teachers should use different teaching-learning approaches in order to increase the impact of the interdisciplinary approach on students (Avsec & Ferk Savec, 2019; Budak Coskun & Altun, 2012; Isik, 2007). In the context of education, participants stated that interdisciplinary activities enable technology integration, enjoyable and effective science education, and efficiency in education. Scanlon et al. (2019) also report that interdisciplinary activities require and develop the use of technology. As Morrison (2006) states, interdisciplinary approaches make it necessary to explain the nature of technology. Moreover, interdisciplinary activities also foster the understanding that science, technology and ethics are integral parts of society (Adams & Baker, 1986).

The third situation investigated in the research concerned the impact of interdisciplinary activities on critical thinking skills and creativity. The responses received from the participants indicate that these activities have a positive effect on critical thinking skills in the context of both the student and the teacher. Especially in the interviews that were held, participants expressed this effect with concepts such as creativity, imagination, thinking skills, real life, and concretization. This finding shows parallelism with numerous studies in the literature. Research has shown that an interdisciplinary thematic learning environment that focuses on real-world challenges encourages students' creative thinking while at the same time encouraging group communication and collaboration. Students also gained skills of inquiry and critical thinking (Ye & Xu, 2023). Montana-Hoyos and Lemaitre (2011) reported that the development of critical competencies and creativity are enhanced through integrative, collaborative, multidisciplinary, interdisciplinary (and hopefully transdisciplinary) instruction, and stated that integrative activities also develop the ability to establish new connections and relationships, which is a fundamental component of creativity. In a study, it was determined that the interdisciplinary learning experience improved the critical thinking ability of the students with the least competence (Zimmerman et al., 2011).

Creative and critical thinking are essential for formulating and evaluating new problems, while interdisciplinarity and multidisciplinary facilitate the transfer of knowledge between contexts. Furthermore, creative and critical thinking skills can complement each other in an effective thinking process and interdependently enable feedback. Put in simple terms, creativity or a different thinking process can provide a wide variety of ideas and opportunities for choosing a possible solution. One of the ways to do this is to use the interaction between disciplines. In this context, by using interdisciplinary techniques, students and teachers will advance in the fields of critical thinking, communication, creativity, pedagogy and essential academia (Jones, 2010). Provided that interdisciplinarity is considered and implemented as an innovative approach across and beyond disciplinary boundaries, it will contribute to the theoretical and practical development of creativity (Darbellay et al., 2017). A recent study conducted by the American Management Association defines creativity as one of the “4Cs” of twenty-first century skills, along with communication, collaboration, and critical thinking (Reilly, 2010). Fillis and Rentschler (2010) state that the increasing role of creativity takes the form of a historical evolution from knowledge-based activities in the economy towards creativity, innovation, entrepreneurship and imagination. The report published by the American Academy of Arts and Sciences in 2013, which refers to “Interdisciplinary Opportunities” as a common theme, calls for “deep integration” between disciplines for both basic discovery and development and application. It is emphasized in the literature that in interdisciplinary approach practices, students’ active participation in the associations between courses and practices within the course also positively affects their critical thinking, creative thinking, logical thinking, problem solving, social communication and higher-order thinking skills (Asunda & Mativo, 2017; Cai & Sankaran, 2015; Chun et al., 2015). In short, it can be said that both within the scope of the research and in the literature, interdisciplinary activities or programs are very effective in the acquisition of other skills and mental processes, especially creativity and critical thinking, which are also included among individuals’ 21st century skills.

## Limitations

In this study, pre-service science and mathematics teachers were studied. Accordingly, the activities mostly consisted of technology-supported interdisciplinary activities in which the disciplines of science and mathematics were integrated. Technology-supported

interdisciplinary activities can be more effective if different branches are also brought together. In this context, the inclusion of participants from different branches in studies can enrich the research and also provide different results. The participants were third and fourth grade students at undergraduate level. The effectiveness of technology-supported interdisciplinary activities can also be examined at different grade levels. Similarly, the technology-supported interdisciplinary activities used in the study were carried out remotely using digital programs such as GeoGebra and Algodoo. The different effects of technology-supported interdisciplinary activities carried out face-to-face can also be discussed. Within the scope of the research hypotheses, the impact of technology-supported interdisciplinary activities on the participants' creativity and critical thinking skills was examined. The effects of such activities on pre-service teachers' 21st century skills, technology awareness or academic achievement can also be examined.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## Funding

TUBITAK financed this course in the 2021/1 term under the project code 1129B372100437 as part of the 2237-A program.

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