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Towards a New Societal Paradigm: The Components, Challenges, and Opportunities of Society 5.0

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ABSTRACT

Editorial

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The research deals with the social evolution of mankind in the historical process and the concept of "Society 5.0", which has recently come to the fore in this evolution. Starting from hunter-gatherer society in the history of mankind, it has passed through the stages of agriculture, industry and information society, and today, with technological advances, a new phase called "Society 5.0" has been transitioned. Society 5.0 is a model of society, especially developed under the leadership of Japan, in which technologies such as artificial intelligence, big data and the Internet of Things are integrated to improve human life. The research examines in detail the reasons, elements, concerns and achievements of this new society model, while emphasising the sustainable development goals.

Keywords: Society 5.0, artificial intelligence, sustainable development, digital transformation

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Reasons, Elements, Concerns and Gains of Society 5. 0

Society 5.0

Mankind has been in a very rapid change since its earliest times. It has undergone great changes from hunter-gatherer, nomadic life to the present day. From tent houses to modern buildings, from hunting and nomadic life to settled and production-based life, from field-straw to tractorfactory, it has made a breakthrough in innovations in its life with the introduction of the internet after the 2000s (Çipi et. al., 2023). There are groundbreaking changes such as moving libraries to homes with the Internet, the use of smart items with the Internet of Things, and the acquisition of artificial homes, spouses, friends and families with artificial intelligence, and in this framework, it tries to gain a place in the metaverse universe by virtualising the world it lives on.

The change of society with the development of technology and science is an inevitable end. In general terms, it can be said that society has reached to version 5.0 starting from 1.0 with its conceptual nomenclature. The following chart summarises the process of social change.

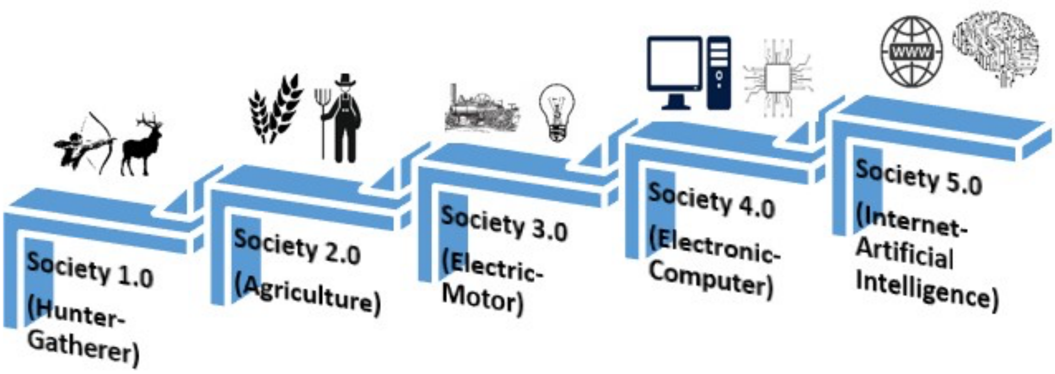

Figure 1. Stages of historical transformation of society

Figure 1 summarises the current state of the society in its earliest form. This chart is inspired by studies such as Arı (2021), Information and Communication Technologies Authority (ICTA) (2021), Eren, (2020), Yetkin and Coşkun (2021), Huang et al., (2022). Below, information about the historical transformation stages of society is given.

Society 1.0 (Hunter-gatherer society): It is the social life of the first years of humanity, the struggle for life, the struggle to feed and temporary accommodation periods. In this period, human beings tend to live integrated with nature (without using resources) and are in the fight for survival.

Society 2.0 (Agricultural society): It is the period when human beings started to use the land with irrigation techniques by switching to settled life. It is the period of forming complex communities and statehood with agricultural production. It is estimated to have started thirteen thousand BC.

Society 3.0 (Industrial society): It is the social structure that started with the formation of industrial periods. It is the society that matured with the first industrial revolutions in the 1800s and the operation of steam mechanics (Industry 1.0) and the spread of mass production with electric and combustion engines in the 1900s (Industry 2.0).

Society 4.0 (Information society): The social difference that started in the 1970s refers to the society in which knowledge and reason are prioritised. It is the society in which the use of electronic and information technologies has increased after the discovery and use of the computer, and production has advanced to an advanced level with automation and robotisation initiatives with the internet (Industry 3.0). Industry 4.0, which is at the forefront of the development of today's society, where the use of digital products, smart production with the Internet of Things, the use of three-dimensional printers, robotics and space technologies supported products are obtained, is also considered within this society.

Society 5.0 (Artificial human): Although this concept first emerged in Japan, it targets the society after the 2030s (Eren, 2020; Yetkin & Coşkun, 2021). First of all, the concept of "artificial human" proposed for society 5.0 should be emphasised. This concept is used consciously by researchers. This concept is not meant to draw attention to the production of artificial human beings or to imply such a situation. As a matter of fact, this concept may have been suggested due to the possibility of such a situation in the coming years with the development of technology. However, this concept, together with the development of artificial intelligence and the Internet of Things, the placement of artificial intelligence in vehicles that facilitate people's daily work, its placement in every home and every family for various reasons, the production of virtual worlds (Metaverse), the realisation of some activities and organisations in these environments, and the fact that life seems to be invaded by the Internet and artificial intelligence, creates the idea that human life is artificialised (the activities that should be done instead of being done for various reasons and making life easier). For these reasons, the concept of "artificial human" is used. However, it is seen that concepts such as "super smart society", "digital society" and "creative society" are attributed in the literature. The main purpose of using these concepts is the definition made by the prime minister of Japan at the time. According to this definition, digitalisation is a philosophical movement that aims to ensure the efficient interaction of people with machines and robots in accordance with their demographic, economic and sociological structures (Arı, 2021; Moradi et al., 2023).

Although Japan experienced a crisis in terms of innovation in the 1990s, it changed its innovation system in order to make a modelling like Silicon Valley and made important studies especially in the fields of biotechnology and information communication technologies with university-private sector cooperation with an entrepreneurial spirit. Nevertheless, there are still thoughts that there is an innovation crisis. For this reason, Japan has put forward the concept of Society 5.0 in order to establish a link between the social needs of society and technological developments (Lechevalier, 2024). In general, Japan has set a path towards a nationwide socialtechnological integration with large financial support and has set an example for the rest of the world. It is also believed that it can have these community-centred innovations (Holroyd, 2022). Japan has implemented 229 smart city projects within the scope of Society 5.0. For example, Maebashi city, where all citizens over the age of 65 are transported by public transport (driverless), is one of these cities. In addition, with bilateral co-operation, cities of other countries, especially the USA, are twinned with each other and similar works are made widespread. In these cities, roads, bridges, tunnels are equipped with smart devices or sensors and measures are taken to prevent serious accidents or injuries by early diagnosis and diagnosis in terms of construction and repair. In addition, interest in autonomous driving is seen to provide great convenience to the elderly population and economy in Japan. This situation also shows that policy makers exhibit a common understanding within the scope of Society 5.0 and progress in improving technology. (Yamasaki, 2024). There are also exemplary applications in the field of health within the scope of Society 5.0. For example, with wearable technology, the health status of the individual is monitored thanks to the sensors integrated into the watch on the arm, ring on the finger or wristband of the individual, and early diagnosis and treatment can be provided with a warning in the most important problem. In another application in the banking sector, banks now serve with digital customer services by opening branches in certain areas and strengthening mobile applications and virtual transactions rather than opening a branch in every province and district (Arı, 2021; BTK, 2021). It is a philosophy that emerged with similarities in the dimension of values and organisations by using the benefits of Industry 5.0 by offering opportunities such as the use of digital objects that can work like humans to prevent risks and accidents in the industry (human's digital twin), providing solutions to society and industry problems with renewable energy sources in order to ensure sustainability (green smart production), and business and professional lives that will change with the developing technology and its integration (Huang et al., (2022). In addition to all these, in the field of education, Turkey has switched from a huge file system containing personnel and student information to virtual platforms such as e-school and MEBBİS. Digital Turkey roadmap, digital literacy course taught in universities, Education Information Network (EIN), Smart intersection, can be considered as the preparatory steps for Society 5.0 (BTK, 2021).

With Society 5.0, it is aimed to get rid of daily muscular labour (BTK, 2021). As a matter of fact, super smart societies have to treat technology as innovations that work for the benefit of society, not as a threat. With Industry 5.0, a collaborative relationship between super smart machines and humans, a fair and sustainable society is envisaged (Coelho et. al., 2023). While previous industrialisation activities were based on technological developments, Industry 5.0 is human-oriented. As a matter of fact, global climate changes, epidemics, migrations and wars require this (Golovianko et. al., 2023). Therefore, it is considered as an intelligent society in which information and communication technologies are fully used, human-centred values are shared and a sustainable future understanding prevails with an egalitarian approach (Eren, 2020).

Causes of Society 5. 0

It is seen that various reasons and developments are effective in the formation of Society 5.0 targets. Sustainable development goals: In addition to some of the basic topics mentioned below, to produce solutions for the rapidly aging world population, especially in Europe. The transition of the economy from Europe to Asia, the necessity of integrating virtual technologies with real life and using them for the benefit of society (Arı, 2021), eliminating ecological problems such as climate change, natural disasters and environmental pollution (Büyükgöze & Dereli, 2019; Eren, 2020), equal and fair distribution of income, including disadvantaged groups such as children, the elderly, minorities, and eliminating gender-based inequalities (Arı, 2021; Eren, 2020), the United Nations published a 17-article manifesto with 3 titles under the name of "Sustainable Development Goals" in 2015, and their recommendations for their acceptance and enactment on behalf of the sustainability of future generations have been effective in laying the foundations of Society 5. 0 has been effective in laying the foundations.

Figure 2. Sustainable Goals (https://turkiye.un.org/tr/sdgs)

The Figure 2 shows the United Nations sustainable development goals (UN, 2024). When these goals are considered one by one;

Goal 1 End Poverty: In particular, to reduce the number of families with a daily economic income of less than $ 1.25 by 2030, to improve at least half of those considered poor at national levels, to ensure that social protection and minimum living conditions are largely implemented. Ensure that every poor and vulnerable individual, male and female, has the right to own, manage and inherit land and property. To reduce the probability of exposure of this class of people to disasters arising from climate and natural disasters. Finally, it aims to create strong infrastructures in the action plans of the countries so that their anti-poverty plans are robust.

Goal 2 End Hunger: By the end of 2023, it includes objectives such as ensuring access to nutritious and safe food for all, eliminating malnutrition, securing sustainable food production by increasing resilient agricultural practices, encouraging small farmers such as maintaining genetic diversity in food production, increasing equal access to land, technology and market, and utilising technology in production.

Goal 3 Healthy and Quality Life: By 2030, end under-five mortality, significantly reduce maternal mortality, combat infectious diseases and tropical epidemics, combat substance abuse and strengthen treatment, reduce road-related deaths and injuries, ensure universal access to information on sexual and reproductive health and reproduction and include it in national strategies, reduce air, water and soil pollution by chemicals and reduce deaths from them, support the development of vaccines against epidemics and non-epidemics

Goal 4 Quality Education: By 2030, guaranteeing pre-primary education and completing primary and secondary education, providing opportunities for vocational training and university education, entrepreneurship and technical training, reducing gender inequality in education, providing literacy and numeracy skills, gaining knowledge and skills on issues such as sustainability, equality, justice, world citizenship, cultural diversity, and supporting the acquisition of skills in information and communication technologies.

Goal 5 Gender Equality: The main objective is to empower women and girls, and it has been determined that societies with strong women and girls have an impact on development in all areas where they ensure economic growth. Eliminating female genital mutilation, early marriage, trafficking in women, sexual and all kinds of abuse, and ensuring equal opportunities in all areas and ensuring that they are included from politics to all levels of management.

Goal 6 Clean Water and Sanitation: By 2030, it is aimed to ensure that people of all age groups have access to clean water, to protect existing water, to recycle and increase the utilisation of water, and to ensure that every individual has access to water in a way that can meet all kinds of special needs.

Goal 7 Affordable and Clean Energy: By 2030, it is aimed to ensure access to affordable, reliable, modern energy services, increase the share of renewable energy sources in consumption, encourage investments in clean energy, and increase greenhouse gas emissions in economies with fossil fuel consumption.

Goal 8 Decent Work and Economic Growth: Increasing per capita income in underdeveloped countries by 2030, opening innovation pathways by supporting the development of technology, significantly reducing the rate of unemployed or uneducated youth, providing decent work opportunities by abolishing forced labour, providing trade and support funds.

Goal 9 Industry, Innovation and Infrastructure: Support sustainable industries with resilient infrastructures, increase research funding by supporting innovative activities.

Goal 10 Reducing Inequality: By 2030, 40 per cent of the population will have a continuous increase in income levels compared to the average, ensuring the empowerment of everyone regardless of differences such as age, gender, race, ethnicity, religion, abolishing discriminatory laws, and managing planned and safe migration policies.

Goal 11 Sustainable Cities and Communities: By the 2030s, it aims to ensure that every individual has access to safe, decent homes, improve affordable, accessible and safe public transport, protect natural and cultural heritage, plan for disaster risks, and manage waste.

Goal 12 Responsible Production and Consumption: It includes sustainable consumption, efficient use of natural resources, waste management, prevention of pollution of air, water and soil, and support for sustainable technological improvements.

Goal 13 Climate Action: It is aimed to strengthen all countries against natural disasters, to prepare national plans for climate change, to take urgent actions with partner states to combat climate change.

Goal 14 Life in Water: Protection of all water resources worldwide, taking measures against wastes, revitalising aquatic ecosystems, preventing harmful fishing practices, increasing marine technologies.

Goal 15 Life on Land: Protection of ecosystems such as forests, wetlands, mountains, drylands, ending deforestation and sustainable management of forests, protection of flora and fauna, taking measures against invasive species.

Goal 16 Peace, Justice and Strong Institutions: It aims to prevent all forms of violence, prevent child abuse, rule of law, prevent corruption and bribery, prevent black money and arms flows to a large extent, make institutions accountable and transparent, and ensure public access to information.

Goal 17 Objectives and Partnerships: It includes issues such as providing international support to countries, increasing the development shares of developed countries for other countries, encouraging the development of sound technologies in appropriate countries, providing trade and economic support between countries depending on the supply-demand situation (United Nations [UN], 2024).

When the sustainable development goals of the United Nations are examined, it is seen that some breakthroughs and regulations are targeted on a global scale. Especially the reference to the year 2030 coincides with the fact that Society 5.0 will officially start in 2030. It can be said that Society 5.0, which was put forward by Japan, was basically shaped based on these goals of the United Nations.

Artificial intelligence: Systems or machines that can repeat themselves with the data they collect by imitating human intelligence (ability-skills). It can be stated as intelligence that can offer the products and services that people want and need in the best quality, provide public or private services equally without discriminating according to people's cultural or demographic values, help them cope with their daily problems, and strengthen general welfare (Calis Duman, 2022; Kocaman-Karoğlu et al., 2020; Sharma & Gupta, 2024).

Internet of things: It can be defined as the network that enables all physical technological devices (air conditioners, TVs, computers, cameras, card readers, GPS, refrigerators, washing machines, etc.) that enter our lives to be made available for human use through software, sensors and the internet and to obtain data from them. The data received from these devices both affect the operation of each other and are recorded in the cloud system for human use when desired (Arı, 2021; Eren, 2020; BTK, 2021). It is realised by connecting the daily used vehicles to the internet by connecting to sensors and microprocessors such as sound, motion and temperature. It provides benefits in many areas from better health care to less energy consumption (van Deursen et al., 2021).

Big data: It refers to the information and data generated by people's use of smart devices. It is used to facilitate people's lives and pave the way for the development of new technologies by collecting and analysing regular habits, increasing or decreasing activities, increasing or decreasing consumption or earnings, raw and dispersed in real time (Arı, 2021; BTK, 2021; Martínez-Gutiérrez et. al., 2024).

Blockchain: With the emergence of cryptocurrencies, their use as a form of money in the virtual world and the subsequent formation of a system of transfers and distribution in the virtual environment, the concept of blockchain was born. This concept means the secure distribution of valuable assets in the internet environment (Xu & Zou, 2021).

Cloud technologies: It is a type of informatics that enables resources to be virtualised and made accessible over the internet with a flexible and dynamic storage area that people can access in any way (Arı, 2021; Kipps & Jones, 2020).

Robotic coding: Robotic coding, which has become widespread especially with STEM education, has been followed and developed with interest by students and young minds. Individuals can code according to their own needs and problem situations and integrate them into robots (Kocaman-Karoğlu et al., 2020; Taniguchi et. Al., 2023).

Digital transformation: It can be said that the most radical work in digital transformation is the concept of digitalisation and metaverse. This concept shows that many jobs and transactions can be done in the virtual universe. Although it is still in the development stage and its functionality has not been fully analysed, it may create an ecosystem between producers and consumers in the future (Piccarozzi et. al., 2024).

Digital twins: It is the production of a product in a virtual environment before the actual object production of a product. In this way, waste and unnecessary costs are prevented (MartínezGutiérrez et. al., 2024; Kumaş & Erol, 2021). Digital twins can be made by integrating the unique values of human beings such as creativity, skills, cognition and decision-making with machines or technology. The digital twin of the human being is the counterpart of the human being that reflects multidimensional information to realise bilateral interaction between the physical and virtual world (Wang et. al., 2024). It seems quite possible when elements such as ethical principles, integration, empowerment, design and ergonomics are taken care of (Panter et. al., 2024).

Sustainability: By moving real-world assets to the cyberspace environment, product and need trials are more profitable than production and trials. Thus, raw material conservation is increased. In addition, workplace accidents and injuries are reduced with tests and trials in digital environments instead of production trials to be carried out in workplaces. As a result, it is promising for a sustainable future to conclude studies in a digital environment with digital twins in order to prevent excess raw material consumption in production-oriented studies such as test-experiments that can be performed on humans, plants or animals and to reach faster results (Tlili et al., 2023).

Elements of Society 5.0

With all these aims and reasons, it is planned that the future society will be differentiated, developed and updated in the following areas:

Houses and cities: It is planned to transition from slums to modern houses with green surroundings, to form smart cities consisting of technological modern houses and to ensure that the basic characteristics of its citizens are instantly known. For example, in the event of a natural disaster or emergency, the city manager will instantly know how many doctors, nurses or engineers there are in the community and will provide disaster control more easily. With the digitalisation of all aspects of state institutions, plans can be made with instant data analysis and sharing (basic needs analyses such as hospitals, kindergartens, schools). Smart home, smart institution and smart city structures can be created with secure digital control systems controlled by the state (Arı, 2021).

Disaster management: Emergency evacuation routes, instant damage assessment and early interventions will be facilitated by utilising the Internet of Things during natural disasters. It enables water, sewerage, natural gas maintenance repairs to be carried out faster after the disaster. It is thought that the risks of loss of life and property will be calculated and reduced to a great extent. By interpreting the data (such as location, status) accumulated through social media accounts, the natural disaster process can be managed faster and more effectively (Mandal et. Al., 2023).

Energy resources: Autonomous power centres will be established with the expansion and increased use of renewable energy sources. Especially with the collection and storage of dispersed energy production, it will be possible to prevent excessive consumption and ensure production according to the need (Hashim et. al., 2024; Sharma & Gupta, 2024).

Health: With the integration of technology and artificial intelligence, the individual will control his/her own health and the individual's health concerns will be reduced by increasing medical access opportunities. With personalised diagnosis and treatment services, diseases will be intervened before they start and their aggravation will be prevented. Research and development activities will be expanded with adequate funding for epidemics or infectious or chronic diseases (El Khatib et. al., 2023).

Food: Remote monitoring and control of agricultural areas will be increased and instant laboratory services will be provided for all kinds of agricultural processes. With the integration of technology, working hours will be reduced and work efficiency will be increased and support will be provided for new harmless food diversification. In addition to terrestrial biological production, it is aimed to increase biodiversity by carrying out production in water. It is thought that agriculture can become popular and receive migration by becoming attractive with technological integration (Parte et. al., 2024).

Logistics: Thanks to the proliferation of the Internet of Things and global connectors, supply chains will be strengthened and features such as instant tracking will be followed up without disruptions. Most importantly, production and consumption balance will be ensured by instantly analysing supply and demand on a global scale by artificial intelligence. Unmanned air transport will come to the fore to reduce logistics volumes in urban areas and to provide comfortable and low-cost transport to mountainous or remote locations (Jamil et al., 2024). With the information integrated into the QR codes on the products (such as audio-visual), the detailed information of all stages in the cultivation of the product will eliminate health concerns and the value of the energy and labour spent in the cultivation of the product will be understood.

Data service: With the instant analysis and correct interpretation of big data with artificial intelligence applications, productions are provided according to the needs of the society and complete services are planned. As a result of artificial intelligence, it is planned to provide production according to all the characteristics of the consumer. Especially with 3D printers, onsite and instant productions can be possible (Hashim et. al., 2024; Parte et. al., 2024). Preventing wastage in all goods and services consumed by people, starting from clothing to cosmetics, will be effective in preventing excessive consumption of raw materials and protecting natural resources.

Finance: Although the possibility of the widespread use of virtual currencies in the virtualised universe is strong, it is planned to live without a material value of human life for a short life. The goal is to ensure life without money or material return or payment. This again seems possible with artificial intelligence. It is planned that life can be easily sustained by calculating the individual's life risk factors (injury-accident) and determining the minimum expenses for the productions they need and meeting them through the insurance system. It is aimed to end all money-related problems with a controller system that is guaranteed to meet the daily needs of the individual without problems such as excess money, black money, reserves with earningsneeds analyses supervised by smart and secure independent controls on a global scale (Arı, 2021; BTK, 2021; Eren, 2020; Er et al., 2021).

Concerns of Society 5.0

It can be said that there are various concerns and uncertainties about the Society 5.0 philosophy and the transition to it. As a matter of fact, these situations are explained below.

Capitalism

Is Society 5.0 the new method of capitalism? Research shows that there are concerns that Japan in particular is taking refuge in this philosophy to overcome the innovation crisis and leave other countries behind (Lechevalier, 2024; Whittaker & Nakata, 2024). Society 5.0 aims for a better society integrated with technology. Here, there is a need for a balance between what is necessary for society and what is necessary for the individual. Digital literacy or technology literacy is required to establish a relationship between society and technology and between the individual and society. Here, the individual needs to collect, analyse, make meaningful and transfer information to daily life. A serious theory and conceptualisation will be needed in this regard (Çipi et al., 2023). A balanced and inclusive planning is needed by integrating Society 5.0 with the United Nations sustainable development goals. Here, whether innovation-based individual goals or the development of companies will be emphasised. As a matter of fact, the relationship between the rates of impact on society when companies grow and the impact of individual development on society needs to be analysed. With Society 5.0, individual gains (for every member of society) should be prioritised instead of corporate gains, and welfare-based activities working for society should be prioritised instead of ruthless business and scientific activities based on competition.

Artificial Intelligence

Can artificial intelligence replace humans? Will artificial intelligence, which emerged with the logic of making people's daily life easier, cause the birth of a lazy and non-working generation? What will happen when artificial intelligence systems or objects produced for human work and operations completely undertake human work? Is there such a possibility? In general, the fact that these are included in a thousand and one questions in the head raises some concerns.

Professions

Since technological developments and artificial intelligence, which are at the basis of Society 5.0, will cause changes in business lines in many sectors, it will cause the birth of some professions in some areas, as well as the lack of need for some professional groups. It is thought that robots will work in areas such as health, education, social work, human resources, software, factory labour, driving, bank clerk, accountant, agricultural labour, customer service and law. It is expected that professions such as bank clerk, clerk, postman, postman, driver, reporter, insurer, accountant, where people are currently working are expected to disappear completely. In addition, it is expected that professions such as electricians, carpenters, plumbers, veterinarians, construction workers will always exist. Finally, professions such as artificial intelligence engineer, data scientist, software engineer, robotics engineer, energy specialist, health technology specialist, mobile application and game development specialist, digital data detective and content producer are expected to be very popular in the future.

Artificial family

The idea that artificial intelligence, the Internet of Things or robotisation entering family life with Society 5.0 will damage or change the institution of marriage is also dominant. As a matter of fact, both a biological and cultural phenomenon takes place in marriages. People can change their perspective on marriage with new technology products that they can talk at home, help with housework and relieve loneliness in a way. As a matter of fact, while the divorce rate in the world was 2 per cent in the 1970s, it increased to 5 per cent in 2008. Again in Europe, nearly half of the couples married in 2017 divorced. It is also known that the rate of having single children in Europe in 2018 was 42.4%. Looking at Turkey, according to the data of 2019, it was recorded that there was a 2.3% decrease in the marriage rate and an 8% increase in the divorce rate compared to the previous year. Finally, it has been determined that marriages are made with robots in some states such as Japan and China (Koçak, 2020).

Human X.0

Starting with Industry 1.0 and becoming 4.0 and 5.0, concepts have emerged up to Society 1.0 and 5.0. After 2030, current technology and science studies are thought to bring new inventions and new concepts to human history. For example, it will not be surprising to see that cloning and human cloning will come to the fore and take place in our lives in the future. It is also predicted that the concepts of human 1.0 and human X.0 will take place in our lives. As a matter of fact, it is thought that we will be considered as human 1.0 or will the generation that made the ancient knowledge or pyramids be considered as human 1.0. But it seems that it is thought that a new human module will take place in our lives through cloning.

Education 5.0

Education 1.0 appears as knowledge-based education. It is the education that is transferred from teacher to student and where memorisation is at the forefront. Education 2.0 is education in which students are considered as factory products while teaching technology is a goal. Education 3.0 is the education in which self-learning has become widespread with the widespread use of the internet and the use of Web 2.0 tools in education. When Education 4.0 is examined, the design and innovative use of technology in education is innovative-innovation processes. It is the individual's use of educational data, creation and support with technology (Er et al., 2021; Laura Icela et. al., 2023). In this education period where the teacher is a mentor, education is continued with integrations such as the Internet of Things, flipped classrooms, personalised data and cloud. Education 5.0 is seen as an educational approach that is estimated as 2030 and beyond and will settle in our lives. It is related to concepts such as digital literacy, digital fluency and the use of artificial intelligence. Here, digital fluency is expressed as the level of utilisation of constantly developing technologies beyond digital literacy. It appears as the ability to keep up with technological transformations with lifelong learning by combining technological developments and learning skills from 21st century skills (Kocaman-Karoğlu et al., 2020). Education 5.0 will be about guiding the individual with smart technologies and machines and shaping his/her educational life (Eren, 2020; Kocaman-Karoğlu et al., 2020). With Industry 5.0, higher education should be integrated with higher education. It is aimed to train individuals who can carry out research and development activities, innovate in their work and focus on human values (Hashim et. al., 2024). With the development of industry, industrial changes and social transformations have taken place in parallel. Similarly, there have been and will be changes and transformations in education. In fact, considering the concrete examples of the changes that have occurred in education to date, it can be said that even if there have been permanent changes in the systems, there has not been an extreme change in student outcomes. Although some state policies or application examples create differences, it can also be said that when the same application is applied to different communities, the results are not at the desired level. Here, the importance of the individual's perspective on education and change in mentality rather than changes in education systems emerges. For example, when the 100-year histories of Japan, Germany and Turkey are analysed, it can be said that in similar years, the three states experienced terrible wars, suffered terrible losses, and suffered significant economic losses as well as territorial and human losses. When their past and present are compared, it is understood that there are differences between the development of the states. It is seen that Japan and Germany have exemplary activities for the world in areas such as economy, industry and technology. However, this is unfortunately not the case for Turkey and it is seen that it is only recently able to talk about itself in the world market. Are the differences between these states due to education? Or is it related to the awareness of their people? In the past, when technology or artificial intelligence was not so advanced, Germany and Japan have made significant progress in terms of economic, technological and welfare. Why has this not been the case for Turkey? Now, when Turkey is equipped with all advanced technologies and education and training is carried out, will there be a significant level of development in terms of economic, technological and welfare?

Gains of Society 5.0

It is estimated that there will be some changes in our lives with the concept of Society 5.0. Although there are concerns with the change, it is also thought that there will be gains.

Although ethics and morality differ according to time and period, today this concept shows that people do all kinds of business and transactions legally or illegally with concepts such as earning more profit, being profitable, guaranteeing their future or being strong. The basis of this is to earn more money and reserve it. With Society 5.0 in future generations, there will be no need for people to fall into this situation or make such plans. As a matter of fact, since equal service (including individual needs) and return according to need will be provided to every person regardless of their status and demographics, and for reasons such as guaranteeing or insuring their life in terms of health and life, it reveals the foresight that human fondness for money will decrease or even disappear. This situation will allow a more moral generation with ethical values to grow up.

- It is possible that there will be daily productions and scientific studies that create value and benefit humanity instead of individuals' worried daily lives such as earning, profit and yield.
- It is thought that there will be a consciousness in which every member of the society, regardless of their demographic characteristics, will focus on human talents and benefits to society with unconditional acceptance.
- Concepts such as developed, developing or poor-rich will disappear over time, and every person will benefit from the same services, and even their education, health and working conditions will be guaranteed by prioritising their individual characteristics.
- It is possible that terrorism or fear-based attacks will come to an end and social peace will be ensured as a result of emotional changes such as the fact that every individual and society is special and valuable with global acceptance.
- It is thought that communities will consist of conscious individuals who are at peace with nature, ready-planned for natural disasters and use sustainable resources and renewable energies as much as necessary.

In parallel with Society 5.0, of course, it is thought that there may be innovations in the field of agriculture. As a matter of fact, primitive agriculture 10,000 years ago (Agriculture 1.0), 18th century horse-ox supported agriculture using crude tools (Agriculture 2.0), 20th century water drainage and machine integrated agriculture (Agriculture 3.0), agriculture using digital machines from planting to medicine, also known as modern agriculture (Agriculture 4.0) and agriculture of the future Agriculture 5.0. 0; It is aimed to collect, process and market large volumes of agricultural data with high profits by taking into account climatic conditions, following weather data, processing soil and crop conditions, producing food with appropriate resource utilisation and preventing waste with technology integrated agricultural machines and internet integration of these machines in meeting the food needs of the increasing population (Parte et. al, 2024). In obtaining products in agriculture, it is thought that large gains will be achieved by using unmanned objects in the process of planting, fertilising, spraying, mowing, harvesting and processing of the products grown with objects that can recommend products to the farmer by providing soil analysis, meteorological data, moisture condition, market situation and supply and demand balance, and marketing it at the right place and time.

DECLARATIONS

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Evaluation Of Design-Based STEM Activities Developed by Science Teachers During Distance Education

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ABSTRACT

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This study aimed to examine science teachers' opinions on distance STEM education and how they evaluate design-based STEM activities they designed and implemented themselves in accordance with the engineering design process. Conducted using qualitative research methods, this study employed a case study design. The participants of the study consisted of 6 science teachers who were doing the Master's in science education at a public university in the Western Black Sea region, Türkiye, in the 2020/21 academic year. The courses were conducted online for one semester. An open-ended interview form, observation notes, and worksheets were used as data collection tools. The data were analysed using descriptive analysis method. Despite the fact that the participants appeared to have found some situations positive, including saving time and space, having the chance to watch the lesson again, easy access to documents, and avoiding health risks, they also found some other aspects negative such as inability of doing group work and having low interaction.

Keywords: distance STEM education; engineering design process; science teachers

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INTRODUCTION

Distance education is a learning process in which individuals in different environments and times can reach each other and relevant resources through distance communication systems. Today, many universities conduct courses through distance education and there is distance education research and application centers in 120 universities (Council of Higher Education [CoHE], 2020). Despite this, the history of distance education in Türkiye is not very long. Distance education has many benefits, such as ensuring the sustainability of education (Akinbadewa & Sofowora, 2020; Omiles et al., 2019; Seage & Türegün, 2020) and reducing educational costs (Al-Husban, 2020; Hall & Knox, 2009) although students and teachers are in different locations. Moreover, barriers such as lack of infrastructure, economic reasons, technical problems, lack of public awareness and regional differences are considered as disadvantages of distance education (Gökdaş & Kayri, 2005).

During the pandemic that emerged all over the world in 2019, universities had to make a very rapid transition to distance education. Every educator with or without sufficient experience in distance education suddenly started to teach through distance education technologies. For this reason, educators sought to find out how distance education could be more effective (Karip, 2020). Since the pandemic, a new system in education has been emerging. With this new understanding of education, the importance of being able to continue uninterrupted learning has been emphasized again, and it is considered that the quality of this education depends on digital access and technological progress (Can, 2020). In order to achieve quality and progress in education, education systems are aimed to raise individuals with 21st century skills. With these skills, there is a need for individuals who can follow the technological developments required by the age, as well as being capable of thinking, researching, questioning and inventing in this connection. It is precisely at this point that STEM [Science, Technology, Engineering and Mathematics] education appears. Integrating disciplines in STEM education is an opportunity to acquire 21st century skills such as responsibility, creativity, collaboration, critical thinking and problem solving (Partnership for 21st Century Skills, 2009). STEM education is also seen as the type of education that enhances life skills, ensures quality learning and the use of existing knowledge in daily life (Yıldırım & Altun, 2015).

Distance STEM Education

Due to the pandemic, the interest in distance education and the increasing importance given to STEM education in recent years and the applicability of STEM education through the distance education approach have come to the forefront, as an issue that is of great importance. As a result of relevant developments, the concept of distance STEM education has emerged to be used (Uyanık, 2021). Despite the use of different expressions (digital STEM, online STEM) in relation to distance STEM education, all of them are believed to serve the same purpose, but vary according to the content of the process (Uyanık, 2021). Distance STEM education means providing STEM education online. It can be defined as education that can be carried out synchronously and asynchronously, assisted by various technological materials, and in a process in which the disciplines of science, technology, engineering and mathematics are handled in an integrated manner, with the active participation of the student. Considering that teachers are the ones who will train students in STEM skills through distance education, it is important to first ensure that teachers participate in the distance STEM education process. For this reason, distance STEM education was carried out synchronously with the teachers in the study.

Studies on STEM education are widely carried out in our country and in the world (Partnership for 21st Century Skills, 2009). However, there are very few studies in the literature on distance STEM education, especially nationwide (Artsın & Deligöz, 2019; Aykan & Yıldırım, 2022; Özkaya, et al., 2022; Tekin-Poyraz & Genç Kumtepe, 2019). While studies on distance education have gained momentum with the pandemic, the number of related studies is still limited in the literature (Artsın & Deligöz, 2019; Chiang, et al., 2022; Gattullo et al., 2022; Jones, et al., 2021; Tekin-Poyraz & Genç-Kumtepe, 2019; Skliarova et al., 2022).

Rationale of the Research and Research Questions

In an era where information and communication technologies are developing day by day, it has once again been seen, owing to the pandemic, that education for new generations cannot be limited to school walls. Nevertheless, there are few studies examining the acceptance of the use of online learning systems, which have rapidly become widespread since the pandemic (Akın et al., 2022). In this ever-changing and developing world, it is necessary to keep up with innovations and to organize our education systems according to new educational trends and to make new reforms in education in this regard. STEM education is an opportunity for us to realize these. It seems necessary to offer STEM education with science teachers via distance education, which became part of our lives with the pandemic as it is obvious that the education systems in the world will no longer be the same as before, and it is highly likely that distance education will not be completely abandoned. In this connection, both the necessary studies on STEM education should gain momentum in our country and new breakthroughs should be achieved on this platform by minimizing the problems encountered in distance education, which is an approach switched to unprepared due to beginning of the pandemic crisis. For these reasons, this study is believed to be important both on account of the lack of sufficient number of studies on distance STEM education and as an example of providing an important approach such as STEM through distance education. The present study is also thought to contribute to the field and set an example indicating that the activities to be implemented within the scope of STEM education can be continued with distance education. At the same time, it is important to study distance STEM education with teachers in the research. Because teachers are primarily responsible for providing students with STEM knowledge and skills. Although face-to-face education is now in place, the necessity of distance education cannot be denied. For this reason, it is important that distance STEM education takes place in the study.

Having taken all these situations into consideration, this study aimed to examine the opinions of science teachers about distance STEM education and the activities carried out in this process in addition to how they evaluated the distance STEM activities they had designed and implemented according to the engineering design process. In order to achieve this goal, 14 weeks of distance STEM education was conducted with the participating science teachers. The problem statement guiding the study can be expressed as: “How do science teachers evaluate distance STEM education and the design-based STEM activities developed in this context?” Within the scope of this problem statement, the sub-problems of the study can be presented as follows:

- How do science teachers evaluate distance STEM education, the activities implemented, and the distance STEM activities they design and implement themselves?
- How can the efficacy of distance STEM education be increased according to science teachers?

METHOD

This study employed the case study design from among qualitative research methods. Case studies are methods in which one or more phenomena, environments, programs, social groups or other interconnected systems are examined in depth (McMillan, 2000). Moreover, the factors related to one or more situations are investigated with a holistic approach. Based on “how” and “why”, a case study allows an in-depth examination of an event (Yıldırım & Şimşek 2011). The case examined in this study is science teachers’ evaluations of distance STEM education and design-based STEM activities developed in this context.

Participants

The study was conducted as distance education in the fall semester of the 2020/21 academic year with 6 science teachers who were doing their Master’s degree at the time in the Department of Mathematics and Science Education at the Faculty of Education of a public university in the Western Black Sea region of Türkiye and taking the elective course “STEM Education Practices”. Participants were selected using purposive sampling method. Purposive sampling allows in-depth examination of information-rich situations depending on the purpose of the study (Patton, 2002). The science teachers were between the ages of 24-38, 2 of whom were male and 4 of whom were female; each was assigned pseudo names, such as Teacher Serap, Teacher Ahmet, Teacher Derya, by the researcher.

Implementation process

This study was conducted in the “STEM Education Practices” course taught as an elective course in the Master of Science Curriculum. It was a 14-week course with three class hours per week. The implementation took place synchronously with distance education due to the pandemic.

The first 5 weeks included the instruction of concepts related to STEM education, its history, the relationship between the related curricula and STEM, as well as STEM-based teachinglearning models such as 5E Learning Model, Project-Based and Problem-Based Learning. In the 6th, 7th and 8th weeks, design-based STEM activities were carried out through distance education within the scope of STEM education practices. After the 8th week, each science teacher executed their own design-based STEM activities. Both the activities carried out by the researcher and the activities designed by the participants were prepared according to the STEM education cycle (Ministry of National Education, 2016), which can be seen in Figure 1.

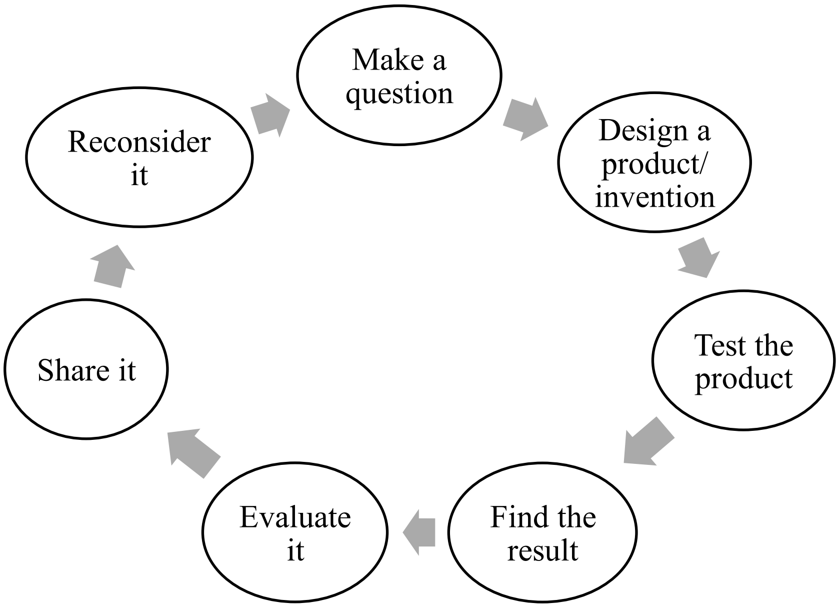

Figure 1. STEM education cycle (MoNE 2016)

The material list of the activities used throughout the lessons was sent to the science teachers via e-mail a few days in advance. The reason why the material list is determined in advance and the same materials are given to teachers is that there are some limitations in the product to be created. Considering the teachers' inability to obtain some materials, alternative materials were also included in the list. Prior to the activities, the worksheet of the relevant activity was shared online on the screen at the beginning of the lesson. Science teachers were given one class hour to construct their designs. In the activities where the given time was not enough, one more class hour was spent online. They sent photos of the products they designed to the researchers at the end of the activity. After the sample activities, the participants individually designed their own activities so that the other participants could be administered the related activities according to the STEM education cycle.

Data collection tools

Data were collected through an interview form, observation notes, and worksheets.

Semi-structured interview form

With the use of predetermined questions in the semi-structured interview form, the data can be presented in a more systematic and comparable way. This provides a great deal of convenience to the researcher (Yıldırım & Şimşek, 2011). The semi-structured open-ended interview form prepared for the purpose of the present study consists of a total of 14 questions to determine the participants' opinions on distance STEM education practices. The participants were asked to express their views on distance STEM education practices, the points they saw as advantages and disadvantages in the STEM activities they had designed and implemented, and as to how the effectiveness of distance STEM education could be increased. In this context, some of the questions asked to teachers are as follows:

1. Did this course help you? If so, how did STEM education contribute to you?

2. If we retconned this course, what would you change and why?

3. At what points did you have difficulty in the activities implemented by the instructor within the scope of the course?

The interviews were conducted online, in an environment where the participants felt comfortable due to the pandemic conditions. The interviews lasted approximately 30-45 minutes. Before the interview, permission was obtained from the teachers to record the interviews. The recorded interviews were transcribed for analysis.

Observation notes

Throughout the process, the researcher observed the teachers during the activity and took field notes. The researcher plays the role of participant observer. As the participant observer, the researcher spent time with the participants at the research process and interview processes (Sönmez & Alacapınar, 2013). The data obtained through observation as a supportive data source for the main data in the semi-structured interview form were used to answer the subproblem of the research that reads, "How do science teachers evaluate distance STEM education, the activities implemented, and the distance STEM activities they design and implement themselves?"

Worksheets

Worksheets were used both in the activities implemented by the researcher and in the activities in which the participants used their own designs. The worksheets were prepared according to the STEM education cycle by using different sources. The prepared worksheets were sent to two experts in the STEM field. Experts were asked to evaluate the worksheets according to the STEM education cycle. Each worksheet included a section where teachers were asked to write down their thoughts about the activity so that the worksheets could be used to support the interview and observation data. A worksheet as an example of the activities implemented within the scope of the study is given in Annex-1.

Data Analysis

The data were analysed using descriptive analysis. In descriptive analysis, the data obtained are summarized and interpreted according to predetermined themes (Yıldırım & Şimşek, 2011). Moreover, direct quotations are used to present the findings to the reader in an interpreted way. While analysing the data, a literature review was first conducted and themes were identified in line with the theoretical framework. The themes determined for the first sub-problem are as follows: "Positive Opinions about Distance STEM Education" and "Negative Opinions about Distance STEM Education". The theme determined for the second sub-problem has been set as the "Suggestions Related to the Course".

RESULTS

The results obtained from the interviews with science teachers, lesson observations, and worksheets are presented according to the sub-problems.

Results related to the first sub-problem

For the first sub-problem, i.e., "How do science teachers evaluate distance STEM education, the activities implemented and the distance STEM activities they design and implement themselves?", the following themes have been determined: "Positive Opinions about Distance STEM Education" and "Negative Opinions about Distance STEM Education".

Positive opinions about distance STEM education

In relation to the theme of "Positive Opinions about Distance STEM Education", two subthemes were identified, namely, "favourable aspects of the process" and "contribution of the process". While analysing the opinions of science teachers in the STEM education process that took place through distance education due to the pandemic, the findings belonging to the subtheme of "favourable aspects of the process" were presented in the form of codes such as saving time and space, having the chance to watch the lesson again, having easy access to information and documents, avoiding health risks, ensuring continuity in education and having fun lessons.

The participants stated that, thanks to the introduction of STEM training course through distance education due to the pandemic, they saved time for students participating from different locations and that they considered it as an advantage to participate in the lessons from home environment. Ahmet, one of the teachers, expressed his thoughts as follows: *"...During distance education, it was a great advantage that participants could access the learning environment from home. In this course, I had classmates from different cities. I think it is advantageous in terms of not having to travel and saving time."* Another teacher, Derya, supported Ahmet's opinion with the following statement: *"I think having remote classes made it easier for the students who attended the lesson. Otherwise, some of my classmates from out of town may not have been able to attend the lessons most of the time, but as it was remote, they could learn about STEM activities without missing the classes"*. This study also revealed from the lesson observations that the participants considered themselves advantageous in participating in the process online. As emphasized by the teachers Serap, Melike, and Derya, time was used more efficiently that way, owing to distance STEM education, and they had the chance to watch the lessons again at times when they missed any lesson. Another teacher, Ceyda said: *"One of the advantages of distance education is that it eliminates distances. In addition, we can go back to the parts of the lesson we missed whenever we want, which is not possible in formal education"*, emphasizing the opportunity to watch the lessons again.

Some of the participants stated that the distance education provided them with the opportunity to access information and documents more quickly in a shorter time. To this end, Murat, one of the teachers, said, *"It allows us to access information, documents, records, etc. related to the subject in a shorter and faster way."* Another teacher, Melike stated that it was very fast to access the lecturer's notifications and presentations about the course thanks to the digital environment, adding that *"...It was very fast to access the lecturer's notifications and presentations about the course thanks to the digital environment."* In addition, Melike's statement in the worksheet that reads, "*We have instant access to worksheets*" supports this view. With STEM education being conducted remotely, the participating science teachers stated that the continuity of education was ensured and that it was suitable in terms of not posing a health risk. In the same connection, Teacher Ahmet said, *"I think the most important positive aspect of distance education is that it does not pose a health risk. I can say that distance education, which is a result of the COVID-19 pandemic in the world, has solved a big problem by ensuring the continuity of education and training activities at all levels in our country despite its limitations."* According to another participant, Gözde, *"The positive aspects of distance STEM education are that continuity can be ensured without the need for classrooms or laboratories alike and that raising awareness by indicating that STEM approach can be applied anywhere. Continuity in education is essential"*, emphasizing that distance STEM learning ensures continuity in education. Some of the participants stated that they enjoyed and had fun during the distance STEM learning process. One of the participants Teacher Murat, for example, said: *"...It is also a really fun course and I really enjoyed every stage of it"*. Similarly, Teacher Serap stated that she enjoyed the theoretical part of the course very much and that she would like to listen to it again, saying that *"I would like to listen to the theoretical part of this course again from the lecturer as it was very enjoyable"*. Course observation data confirm the outcome that the participants had fun during the lesson. In addition, when the activity worksheets of the teachers were analysed, the teachers personally stated that they enjoyed each activity.

Furthermore, the participants stated that the distance STEM education process made a positive contribution in many aspects, such as learning and applying the STEM approach, generating solutions to problems, adapting science and mathematics outcomes to STEM, preparing lesson plans and facilitating the applicability of the STEM approach in lessons. They also pointed out that, through the distance STEM education course, they made better sense of STEM education, whose popularity they had heard of, and that it started to attract their interest. In a similar context, Teacher Serap said, *"STEM is a popular concept that I have heard a lot about, but I had never received any training on it before. That's why I took this course, and as the course progressed, I read more about it, so the STEM approach started to interest me more"*, and stated that her interest in STEM education increased. On the other hand, some participants stated that they misidentified STEM education before taking this course and believed that its applicability was quite low; however, after taking the course, they seemed to realize that they learned STEM education more accurately, saw that its applicability in lessons was higher, and learned to come up with solutions to problems. As another example, Teacher Derya mentioned about the contributions of the lesson as follows: *"I think it contributed a lot because I realized that I had misunderstood STEM education at first. Now I know that activities should be done with the materials at hand. I thought that more complicated and flawless projects should be produced; however, after this course, I learned that we can come up with a solution to a problem with any material we have at home and that the solution produced is rooted in the STEM education itself."* In addition to his previous comments, Teacher Ahmet also said *"Before taking the course, as a teacher, I thought that the applicability of this approach was lower. Since taking the course, however, my opinion about its applicability has changed positively. I believe that STEM-based educational practices should be used in lessons. I chose the course because I have been interested in STEM education, and now I am happy to have more information about this approach"*, and emphasized the contribution of the process to the teachers. During the lesson observations, the participants appeared to have misconceptions about STEM education in the first week, yet changed over time.

Some of the participants stated that they came up with solutions to the question: "How can I adapt the subjects and intended learning outcomes to STEM education?" thanks to distance STEM education and related activities. In this direction, Teacher Murat said, *"It definitely contributed. Now, for every lesson I will teach, I have started to think about how I can make use of STEM education for the benefit of my students."* Similarly, Teacher Serap said, *"...the emphasis on the use of the STEM approach in science learning outcomes attracts my attention. When teaching a subject, I first think about how the STEM approach can be used for that particular subject matter"*. In addition, some participants also stated that their STEM education contributed to preparing lesson plans according to different learning styles (e.g., Teacher Ceyda). Likewise, Teacher Melike stated the contributions of STEM education and said: *"It definitely made a very clear contribution. I think it is really useful in terms of preparing lesson plans according to different learning styles and gaining a general understanding"*.

Negative opinions about distance STEM education

The two sub-themes belonging to the theme of "negative opinions about distance STEM education" are: "undesirable aspects of the process" and "difficulties experienced in the process”. The codes belonging to the first sub-theme are: inability of doing group work and low interaction. The participants stated that communication skills were unlikely to improve since group work could not be conducted during the distance STEM education. In this context, one of the participants, Teacher Ceyda, said: *“The lack of group work means that students cannot gain communication skills properly. In group consciousness, a higher sense of responsibility can be achieved”*, in order to emphasize the aspects, she did not like in the process. Similarly, Teacher Serap supported Ceyda’s words when she said: *“I would prefer to have done the activities in groups, interactively. We could not do it this way in remote learning.”*

As for the undesirable aspect of the process, two of the participants- Derya and Ceyda- stated that it would not be possible to advance STEM education, which is oriented towards practice, just by looking at the screen during distance education since some information remained in theory. In this connection, Derya shared her views and said: *“...Some subjects remain in theory and there are problems in practice.”* Teacher Murat, likewise, said: *“I liken distance STEM education to a barber teaching his apprentice how to shave remotely. I mean, STEM education, which is completely application-oriented, is not as useful when it is done remotely. I believe that being able to put into practice the knowledge and training received through distance education is also directly related to the ability of the apprentice”*, by exemplifying his views in an effort to express the aspect of distance STEM education that he found undesirable.

Under the sub-theme of difficulties in the process are the codes such as the difficulty of communicating through a camera, going through the product design stages, providing necessary materials, having insufficient time, building an internet infrastructure and having technical problems. It was clear that science teachers had difficulties in the stages of designing their products during the lesson within the scope of STEM activities. In this connection, Teacher Melike said that she had difficulties while testing and sharing the product she designed within the scope of the activity in the distance education environment, and Teacher Ahmet said: *“I had a lot of difficulty when I was asked to show the design I made in front of the camera to other participants and to test this design at the same time. I couldn’t do it and then I had to send the video of it later”*, in line with Melike’s words. Similar to the other participants, Teacher Murat stated that he had difficulty in showing and explaining the products he made through the camera and that he had difficulty in the drawing phase of the design stages. Teacher Derya also stated that it was both difficult and time-consuming to think about the problem and create a prototype for its solution. Both observation data and worksheets support what the teachers stated. Lesson observations also show that teachers had difficulties especially at the product design stage. Derya also added that one of the difficulties of the participants in the distance STEM education process is the difficulty in providing materials for the activities to be implemented within the scope of STEM education. In the same context, Teacher Ceyda clearly stated that she had difficulty in finding materials due to the pandemic, but other than that, she mentioned no other challenges, but a lot of fun: *“Sometimes I had difficulty finding materials due to the pandemic, but other than that, I had no difficulty at all. We had a lot of fun.”* Some participants stated that they had difficulties in terms of material supply due to the late receipt of the material list (the participants namely, Serap and Melike). In this context, Teacher Melike expressed the difficulty she experienced in providing materials with her following words: *"It should have been much easier and earlier for us to receive the activity material lists".* Some participants also indicated that the problems arising from the internet infrastructure in the process created communication problems and made it difficult to understand some issues. At this point, Teacher Ahmet expressed the difficulty he experienced as follows: *"Internet infrastructure and other softwarerelated problems in distance education make effective communication difficult and may prevent some subjects from being understood sufficiently or examined in more detail."* Furthermore, Ceyda also stated that she could not see the designed products clearly when they were presented because of the poor screen quality from time to time and that she experienced some problems due to the internet: *"...We cannot see the product clearly during its presentation. The screen quality is poor and there are sometimes problems on the Internet.*"

Results related to the second sub-problem

As for the second sub-problem: "How can the efficacy of distance STEM education be increased according to science teachers?", a theme was determined as "Suggestions related to the course".

Results related to the "Suggestions for the Course"

The codes under the theme, "Suggestions for the course", comprise the aspects indicating that the course and activities should be conducted face-to-face, the design and materials should be told in advance, the duration of the course should be increased, coding should be added and different resources related to STEM should be included. Most of the participants stated that STEM activities would be more efficient and effective if the distance STEM education was provided through face-to-face education. Teacher Derya stated: *"...it would have been more productive if we had carried out STEM activities face-to-face"*. In one of his suggestions about the course, teacher Murat stated that he would like to change the way the course is offered and since it is based on practice, thus it needed to be provided face-to-face. Teacher Ahmet stated that although distance training was conducted with some shortcomings, he would prefer to have taken the course face-to-face and that even the most successful distance learning remains incomplete compared to face-to-face education. Unlike the suggestions of the participants indicating that the course should be offered face-to-face, Teacher Melike did not make any suggestion about the course as distance learning with her statement: *"I would not want it to be changed because I think there would not be a big difference between face-to-face and distance training courses"*.

Some of the participants suggested that the activity to be designed should be assigned as homework before the lesson and the design should be described in advance so that it would be easier to obtain materials (Melike). In the same context, Teacher Serap stated her opinion as follows: *"...I thought it would have been better if the design was assigned as homework before the lesson, so we could provide the materials we wanted to make the design with."*, and in another statement of her, she added: *"There is nothing I want to change in the way the lesson is* *taught. It is effective and efficient. I would like to listen to the theoretical part of this course again from the lecturer, it was very enjoyable"*, yet she gave no suggestions. One of the participants, Murat, suggested that the lesson be extended in terms of its duration so that more creative ideas would emerge, and he added: *"...I would also like to extend the duration of the lesson because if there was a little more time, more creative ideas and products could emerge"*. In order to make the lesson more effective, Melike, stated that: *"Maybe it would be better if we added some coding. Another drawback I saw was that various STEM resources (digital or printed) were not included. For example, an article based on a sample STEM activity could have been included.*" Some of these participants indicated that everything was very good and that they did not want to change anything about the course (i.e., teachers Ceyda and Ahmet).

Conclusion and Discussion

According to the results of the study, the science teachers found certain aspects, i.e., saving time and space, having the chance to watch the lesson again, and providing easy access to information and documents as positive with respect to distance STEM education. Some other research results exist in the literature supporting the data obtained in this study (Aykan & Yıldırım 2022). Kazanidis, et al. (2015), and evaluate how university students participating in a distance STEM course benefited from the process and the adequacy of this process in terms of STEM learning; the results revealed that the students reported positive opinions about the teaching capacity of the distance STEM training course. Similarly, Burke and Dempsey (2020) identified the issues that teachers found advantageous regarding the education during the pandemic; their participants emphasized that they had the opportunity to get acquainted with digital education platforms and that such a training would save time and practicality in terms of accessing some resources and materials.

The fact that distance education does not pose a health risk, ensuring continuity in training and the course being fun are among the other results of the study, which were emphasized by science teachers as the popular aspects of the process. Moreover, it was revealed that distance education raised the awareness of teachers that STEM education can be applied anywhere. Tekin-Poyraz and Genç-Kumtepe (2019) reported that if STEM learning is supported by distance education, it can reach disadvantaged groups who cannot go to school for various reasons (e.g., due to disabilities, illnesses, or living in rural areas, etc.) and they can have access to STEM education. Yusuf, et al. (2021) mentioned the necessity of distance education, especially during the pandemic, and the science teachers as the participants of that study stated that the STEM education offered through distance education had many contributions, indicating that the process contributed to learning the STEM approach and being able to apply it. Similarly, Artsın and Deligöz (2019) conducted a conceptual evaluation study on science, technology, engineering and mathematics education in massive open online courses. According to the study, if STEM education is provided through massive open online courses, STEM-based activities will be visible to a wider audience, thereby raising social awareness, and making contributions to developing countries and individuals alike. Moreover, the opinions of science teachers in that study indicated that being able to adapt the intended learning outcomes in science and mathematics to the STEM approach and to prepare lesson plans in line with this are also among the contributions of the distance STEM education process.

The results of the present study also show that despite the positive opinions teachers reported about distance STEM education, the activities implemented as well as the ones they designed and implemented themselves, they still had negative opinions. They stated that the lack of being able to do group work, low interaction and the course remaining in theory were the negative aspects of the process while learning about the STEM approach through distance education. In another study, Hebebci, et al. (2020) reported that some teachers had positive opinions about distance education, while others stated that high levels of interaction and social communication could not be easily achieved in distance education as in face-to-face education. Moreover, Başaran et al. (2020) aimed to obtain information about the efficiency of the distance education process by examining the views of teachers, students and parents on distance education during the pandemic process. Similar to the results of the present study, the authors demonstrated that the participants mentioned positive aspects of distance education, in addition to the negative aspects related to the limited interaction. Additionally, the fact that teachers found it very difficult to communicate via computer while testing, sharing and presenting the products they designed within the scope of STEM activities appeared as another problematic situation they experienced in the process. There are studies in the literature that show similar results with the teachers' negative opinions about the distance STEM education (Aykan & Yıldırım, 2022; Bulut et al., 2022; Skliarova et al., 2022; Özkaya et al., 2022).

Most of the science teachers who made suggestions about the course stated that the activities related to the STEM learning provided through distance education due to the pandemic should actually be performed face-to-face. Niemi and Kousa (2020), for example, aimed to reveal the views of teachers and students in a secondary school in Finland during the pandemic about the process and activities. The authors demonstrated that teachers had negative opinions indicating that distance education cannot provide the naturalness achieved in face-to-face education, that a quality learning process cannot be experienced and that the quality of interaction remains low. In the current study, some of the science teachers stated that it would be better if the design to be made within the scope of the activity was assigned as homework before the lesson and told about in advance, and that, knowing the design in advance would make it easier to obtain materials. Tekin-Poyraz and Genç-Kumtepe (2019) demonstrated that with the help of distance education, students can prepare at home for STEM activities to be done at school, or STEMrelated activities that cannot be done at school can be experienced at home. In this respect, it is in parallel with the suggestions of the participants of this study when they emphasized that the design to be created should be informed in advance. Another issue suggested by the participants was to extend the duration of the course, in which way, as they emphasized, more creative ideas and products could emerge. Some participants also stated that it would be beneficial to add coding to the distance STEM education course and that different resources related to STEM should be included.

The results show that the opinions about distance STEM education are mostly positive. For this reason, it is recommended to conduct more studies on distance STEM education so that its content can be enriched. Since the participants stated that they would implement the designbased STEM activities they designed in their classrooms, seminars on design-based STEM activities can be provided for teachers. This study focuses on distance education, demonstrating that teachers have some negative views about it. It is suggested that future researchers should take these views into account and design future studies accordingly. Combining face-to-face and distance learning, blended learning may also be suggested in this regard.

DECLARATIONS

Ethical Considerations : The study was voluntary and anonymous for all participating science teachers. Necessary permissions were taken from the Ethics Committee of Zonguldak Bulent Ecevit University (Protocol number: 913). In terms of ethical considerations, the participants were provided with information about the purpose of the study, confidentiality of their data, and the voluntary nature of their participation.

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ANNEX-1

A worksheet as an example of the activities **Problem**

Statement:

J-STEAM
Journal of STEAM Education
Journal of Science, Technology, Engineering, Mathematics and Art Education
2024, Jun. (Issue: 2, Volume: 7)
STEAM Eğitimi Araştırmaları Derneği

Umut'un pandemi sürecinde en yakın arkadaşı minik balığı Turuncu' dur. Umut minik balığı Turuncu' nun oynayabileceği, ona arkadaşlık edebileceği bir denizaltı balık tasarlamayı düşünmektedir. Tasarlamayı düşündüğü denizaltı balık; bir balık gibi su üstünde yüzebilmeli ve su altına batabilmeli, ayrıca su içinde askıda kalabilmelidir.
Pekiyi arkadaşlar "Hem su üzerinde hem dipte yüzebilen hem de su içerisinde askıda kalan bir denizaltı balık modeli nasıl yapılabilir?"

Material List:

Etkinlik için gerekli malzemeler şunlardır:

- 500 ml'lik iki adet pet şişe,
- 15 adet bilye,
- 15 adet pipet,
- Selobant (yapıştırma amaçlı),
- Tornavida ya da delici başka bir cisim,
- Makas,
- 3 adet balon,
- 1 kutu oyun hamuru,
- Geniş plastik kutu (yüzdürme havuzu),
- Su

(Verilen malzemelerin hepsini kullanmak zorunda değilsiniz. Malzeme kullanımı konusunda özgürsünüz.)

Rules:

Kurallar:

- ✓ Tasarladığınız denizaltı balık modeli su üzerinde yüzebilmeli,
- ✓ Su altında yüzebilmeli (batabilmeli),
- ✓ Su içinde askıda kalabilmelidir.

Make a Question:

PROBLEME YÖNELİK SORU OLUŞTUR (BİREY/GRUP ARAŞTIRMASI VE TARTIŞMASI):
(Aşağıdaki sorular yapacak olduğunuz denizaltı balık modelinize yol gösterecektir.)

1. Canlılar suda nasıl yüzmektedir?

2. Denizde veya havuzda olduğunuzu düşündüğünüzde suyun üzerinde hareketsiz kalmayı nasıl sağlayabilirsiniz?

3. Dalgıçlar suyun içerisinde nasıl kalabilmektedir?

Design a Product:

ÜRÜN/BULUŞ TASARLA
(Hayal Etme, Planlama ve İnşa etme)

- Tasarlamayı düşündüğünüz denizaltı balık modelini çizelim.

- Tasarımınızda hangi malzemeyi, ne için kullanmayı düşünüyorsunuz?

- Modelinizi inşa edin. Aşağıdaki boşluğa tasarımınızı inşa ederken neler yaptığınızı <u>sebepleri</u> ile birlikte yazın.

Test the Product:

Journal of STEAM Education
Journal of Science, Technology, Engineering, Mathematics and Art Education
2024, Jun. (Issue: 2, Volume: 7)

ÜRÜNÜ TEST ETME
Ekranda herkesin görebileceği bir şekilde,

- Verilen malzemelerle denizaltı balık modelinizin tasarımını yaparak yüzebilir, askıda kalabilir ve batabilir hale getiriniz ve test ediniz.
- Test etme süreci bireysel/gruplarla birlikte gerçekleşecektir.
- Bu süreçte tüm yaptığınız modelin tasarımı anlatınız.

Find, Evaluate and Share the Result:

SONUÇ ÇIKAR/DEĞERLENDİR VE PAYLAŞ
(Yapılan tasarımlar ile ilgili sonuçları ve değerlendirmeleri paylaşma)

- Model istenilen 3 özelliği de gösterebildi mi? (yüzme, batma, askıda kalma)
- Modeli tasarlarken hangi bilimsel bilgileri kullandınız?
- Etkinlik sırasında ne tür sorunlar ile karşılaştınız ve bunları nasıl çözdünüz?
- Sizin yaptığınız modeldeki kısımlar balıklarda hangi kısımları veya organları temsil etmektedir?
- Denizde daha derinlerde yüzmek istiyorsan ne yapmalısın?
- En çok hangi grubun/öğrencinin modelini beğendiniz neden?
- Bu etkinliği yapmak size neler kazandırdı? Bu etkinliği yapmak sizce neden önemlidir?

Reconsider:

YENİDEN DÜŞÜN
Değiştirme/Geliştirme

- Tasarladığınız denizaltı balık modelinizde ne iyi çalıştı ve ne iyi çalışmadı?
- Tasarladığınız denizaltı balık modelinizi değiştirmek/geliştirmek için neye ihtiyacınız var?
- Değiştirdiğiniz/geliştirdiğiniz denizaltı balık modelinizin taslağını çiziniz

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Pre-Service Mathematics Teachers' Experiences In Designing STEM Lessons

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Research Article

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ABSTRACT

This study aims to investigate the views of pre-service mathematics teachers on STEM education and the challenges encountered during the lesson planning process. The qualitative research method was utilized for in-depth analysis. In the study, pre-service mathematics teachers were engaged in activities related to STEM that the researchers prepared. After this, they were asked to create and teach lesson plans focusing on STEM. In order to get more information about their experience, three interviews were conducted with them at the beginning, middle, and the end of the study. Analysis of the interviews revealed significant changes in the pre-service teachers' comprehension of STEM education. Furthermore, it was observed that the participants could integrate mathematics and science into their lessons more easily than engineering and technology disciplines. The participants who stated that the integration of mathematics and technology is important could not actually perform this integration effectively. Finally, the participants stated that STEM education is an essential educational approach within mathematics education, expressing their intentions to incorporate STEM activities into their future lesson plans.

Keywords: STEM Education, STEM Lessons, Interdisciplinary Approach, Lesson Planning, Pre-service Mathematics Teachers, Challenges

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INTRODUCTION

In this era, people are expected to keep up with the rapid advancement of technology (Chai et al., 2020). It is essential to stay current with change and be a part of it in all areas, including those of personal nature that impact daily lives. STEM education aims to propel economic progress and raise creative leaders who can catch up with the information and knowledge age (Wijaya et al., 2022). It is important in transforming theoretical knowledge into tangible products and fostering the acquisition of indispensable 21st-century skills such as creativity, strong communication skills, critical and analytical thinking, and the ability to cooperate. Countries that can produce, develop, and effectively utilize knowledge have distinct advantages in terms of economic indicators. McKay (2020) asserts that STEM education is a powerful method for teaching critical thinking processes, making judgments, and making decisions. It allows students to use theoretical knowledge about mathematics and science in daily life. Therefore, STEM education serves as a compass, effectively portraying the essential relevance of mathematics. STEM education helps students understand why they are learning these contents, and understanding the purpose behind the lessons positively affects students' motivation (Bybee, 2010).

STEM education offers pre-service teachers valuable knowledge concerning various learning approaches and effective methodologies (Wijaya et al., 2022). Nevertheless, research by Pimthong and Williams (2021) has shed light on a prevalent shortcoming: many pre-service teachers need an adequate grasp of STEM education's fundamental principles. The imperative for well-prepared educators in STEM education is emphasized by Çalış (2020). In order to provide an efficient STEM education environment for students and to facilitate the formulation of comprehensive lesson plans, it is crucial and necessary to train pre-service teachers in this domain. Given that teachers' proficiency and experiences in STEM fields significantly influence students' learning outcomes, the professional development of educators assumes a pivotal role in advancing STEM education (Margot & Kettler, 2019; Zhang & Zhu, 2023). Furthermore, Basu et al. (2021) contend that collaborative engagement with pre-service teachers holds substantial promise for propelling the development of STEM education. Considering the importance of STEM education and teacher education, this study thoroughly examines the lesson planning process for STEM education. By revealing the challenges encountered during the formulation and enactment of STEM lesson plans, this research suggests valuable implications for teacher educators and researchers.

Literature Review

STEM Education

Science, technology, engineering, and mathematics (STEM) education is a form of education that combines these subjects and shows learners how these fields are linked in real life scenarios

(Fitzallen, 2015; Johnson, 2012; Marrero et al., 2014; Pimthong & Williams, 2018). When teachers use curriculum integration, the contexts can be given with all necessary details in other disciplines, establishing robust links to real-world applications (Corlu et al, 2014). The conventional approach of teaching disciplines as isolated entities often fails to mirror real-world practice, while STEM education actively seeks to fuse various disciplines together (Sian Hoon et al., 2022). It aims to raise new generations with awareness of innovation. Through STEM education, students can learn interdisciplinary skills that are essential for life (Corlu et al, 2014; National Research Council, 2011). Education offers a unique opportunity to harmonize and amalgamate all academic disciplines, fostering an environment where students can engage in holistic learning experiences. The implementation of an integrated STEM education approach has been shown to enhance student learning (Anderson et al., 2020; Bartels et al., 2019).

A substantial body of research highlights the advantages of STEM education. Researchers suggest that STEM education should be considered as an approach and be integrated into diverse subject matter. STEM education is directly related to life; therefore, according to Şahin and Yıldırım (2020), it helps to shape students' perceptions about professions. Suratno et al. (2020) states that there is a positive relationship between students' problem-solving skills and achievements with STEM education model. Moreover, Aydın (2020) posits that STEM education is an effective method to give students motivation and courage for creativity, problem solving and invention, especially in early grades. Similarly, both Anderson et al. (2020) and Zhang and Zhu (2023) affirm that STEM education equips students with the aptitude for innovative problem-solving when faced with challenging situations.

According to Bybee (2010), STEM education, an interdisciplinary approach, must support literacy in each STEM discipline. Science and mathematics are disciplines that are typically offered as distinct courses. This segregation is reflected in the provision of separate science and mathematics education programs. In light of technological advancements, the significance of integrating technology into all academic domains has gained prominence. Conversely, within the realm of STEM education, engineering stands out as one of the disciplines lacking a dedicated primary-level course. Consequently, the interpretation and implementation of engineering integration within STEM education assumes particular importance (Yata et al., 2020). The definition of engineering varies among sources. Some researchers define engineering as a profession. However, in STEM activities, Yata et al. (2020) defines engineering as a creative activity. On the other hand, Kelley and Knowles (2016) define engineering as a design process.

Pre-service Teachers' Views on STEM Education

Teachers who eagerly delve into STEM education experience a noticeable boost in their teaching confidence throughout their educational journey. STEM education practices support pre-service teachers' self-confidence (Sian Hoon et al., 2022). Moreover, this process heightens their understanding of real-world contexts and underscores the pivotal role of a comprehensive education (Berlin & White, 2010; Corlu et al., 2014; Darling-Hamond, 2006). Firstly, teachers must be familiar with the successful implementation of STEM activities. Understanding what teachers and pre-service teachers think about STEM education is essential. Hence, a substantial body of research is dedicated to STEM education, and investigations concerning perspectives on STEM education hold a significant position within this field. According to Pimthong and Williams (2021), the absence of a robust emphasis on STEM education in pre-service teacher education programs hinders the effectiveness of pre-service teachers, particularly those trained in single disciplines, in adopting interdisciplinary approaches.

Consequently, Pimthong and Williams (2021) advocate allowing pre-service teachers to craft lessons and engage in STEM teaching before completing their education. In alignment with this perspective, Wijaya et al. (2022) assert that the integration of STEM Post-workshop analysis revealed a noteworthy improvement in the participants' STEM knowledge, leading Berisha and Vula (2021) to conclude that the workshop had a positive impact on enhancing pre-service teachers' understanding of STEM concepts. Education in teacher training programs is imperative for nurturing 21st-century skills. Therefore, including STEM education practices within teacher education programs becomes essential (Anderson et al., 2020). However, Zhang and Zhu (2023) argue that the current STEM learning experience within teacher education programs needs improvement and enhancement. Berisha and Vula (2021) investigated the STEM knowledge and awareness of pre-service teachers. Despite limited prior experience with STEM activities, these pre-service teachers exhibited substantial dedication to advancing their own STEM proficiency (Sian Hoon et al., 2022).

Çalisici and Sümen (2018) highlight that prospective mathematics teachers consider STEM a beneficial and indispensable approach that integrates complementary fields, garnering significant appreciation. According to Pearson (2017), pre-service teachers should be encouraged to understand the combination of different disciplines. Engaging in STEM education initiatives is valuable, but practical implementation goes beyond mere participation. To achieve a genuinely successful STEM education application, teachers need to possess a profound understanding of STEM principles. The depth of their familiarity with interdisciplinary education influences the efficacy of their growth and competence in this domain. The more they immerse themselves in and contemplate interdisciplinary approaches, the more powerful their progress and impact become. Teachers can observe the connections between science, technology, and engineering more clearly while preparing a lesson plan related to their field. This makes it easier for them and students to see mathematics clearly in all areas of life. Therefore, preparing a STEM-related lesson plan is critical for teachers to understand STEM education better.

As highlighted by Corlu (2014), educators often commence their careers without the essential integrated teaching knowledge required for effective STEM education delivery. This underscores the pressing need for enhancements in teacher education about STEM instruction.

Maiorca and Mohr-Schroeder (2020) examined pre-service teachers' lesson plans. In the context of this study, pre-service teachers engaged in a STEM education activity and subsequently crafted STEM lesson plans upon completing their field experience. The study's findings indicated that almost all pre-service teachers incorporated problem situations necessitating engineering design and data collection into their lesson plans. Additionally, Bergsten and Frejd (2019) concluded that prospective mathematics teachers could produce integrated STEM course proposals by combining different disciplines. Cahyono et al. (2021) also investigated the potential for enhancing the 21st-century skills of prospective mathematics teachers by developing a STEM course model. They found that incorporating STEM education into teacher education programs is essential for prospective mathematics teachers. Consequently, providing pre-service teachers with opportunities to participate in integrated STEM activities likely enables them to observe the positive impacts of STEM education.

Furthermore, a substantial body of research has explored pre-service teachers' perceptions of STEM education, consistently revealing optimistic outcomes among teacher candidates. The prevailing consensus among researchers strongly advocates for including STEM education within undergraduate teacher training programs. However, it must be noted that most studies on this topic have primarily centered around science and technology (Bergsten & Frejd, 2019; English, 2016), indicating a potential need for a more comprehensive exploration across various teaching disciplines.

Despite a large body of research that indicate the importance of STEM education as mentioned above, there is a scarcity of studies that include lesson plans of pre-service mathematics teachers engaged in STEM based teaching activities. The present study aims to address this gap by conducting a detailed case study of three pre-service mathematics teachers as they engage in such a learning and teaching experience.

METHOD

Research Design

The qualitative research method, multiple case study, was used in the data collection process. Qualitative research design provides a detailed understanding of the participants and the process. It not only focuses on the outcome but also examines how participants understand the study and how it affects their behavior (Maxwell, 2008). The data obtained from the semistructured interviews were analyzed according to the content analysis process (Fraenkel et al., 2019). Since the interview questions aimed to gather general knowledge about STEM education, we identified themes and patterns within the interview responses using content analysis. These categories included STEM components, advantages of STEM education, challenges in STEM education, and teaching strategies. This study examines pre-service elementary mathematics teachers' views on STEM education, their STEM lesson planning process, and the challenges they experience in the lesson planning process. The research titled "Investigation of Prospective Teachers' Views on STEM Education and the Difficulties Experience in the Lesson Planning Process" was approved by the Middle East Technical University Human Research Ethics Committee on 14 January 2022 with the number 28620816 and protocol number 0018-ODTUİAEK-2022.

Participants and Context of the Study

In this study, the convenience sampling method was utilized. In other words, the study was carried out with volunteer participants who met the desired conditions. The participants were final-year students of an elementary mathematics education program at a large public university in Ankara, Türkiye. During the data collection period, they took the Teaching Practice course in the spring semester of 2021-2022. After the aim and data collection process of the study were explained, among the 10 students that were enrolled in the course, 6 of them volunteered to participate in the study. Preparation of a STEM lesson plan was not compulsory as part of the course, and pre-service teachers who chose not to participate in the study had the option to prepare lesson plans based on their own preferences or desires. In this study, three of the six volunteer students were selected based on their lesson plans. Participants selected for the analysis were more excited and enthusiastic to participate in the study, and their lesson plans were more detailed. These participants are referred to as with the following pseudo names in this paper: Robert, Claire, and Sarah.

Sample Lesson Plans

During the course, pre-service teachers prepared two lesson plans. In this study, the participants were asked to prepare their lesson plans based on STEM education. Although this may seem difficult for pre-service teachers who have never participated in a STEM education activity before, most of the class was eager to gain experience in STEM education before graduation. After the participants prepared their first lesson plans, the researchers implemented STEM education activities during the course hours in April. Four STEM education lesson plans prepared by the researchers were implemented as sample lesson plans. These teaching sessions were conducted with the participant's consent and were recorded for analysis.

The first lesson plan is designed to explore linear equality through a bungee jumping activity. The participants were divided into three groups, each assigned to its station. There was a meter on the wall at these stations, and participants were asked to envision this location as a bungee jumping platform. Each group was provided with an activity sheet, a rubber band, and a bottle, which were prepared before the lesson. A bottle was used for this activity due to its easy accessibility and low cost. The groups, equipped with these materials, were then instructed to begin the activity. Their task was to calculate how many meters the bungee jumping station was above the ground by gradually extending the rubber band attached to the end of the bottle. Since the water in each bottle could vary, the heavier bottle would fall lower. As a result, participants concluded that one's weight needed to be considered when ensuring a safe landing for bungee jumping. They drew the graph and found the equation of the best-fit line. It was concluded that the person's height should have been added as a constant if the model jumped with its feet tied to the rope at the bungee jumping station.

Figure 1. Pre-service teachers conducting experiment at their designated bungee jumping station.

The second lesson plan was an activity aiming to develop table reading and comparing two data sets. Participants were asked to think about the characteristics of bridges and the factors that might be involved in the bridge collapse. Each group was told that they were the engineers who would rebuild this bridge. Four different types of bridges were presented, and they were expected to calculate the cost of each of these bridges. Each group chose a bridge according to their criteria. The participants were expected to present their bridge design at the end of the lesson. These criteria were the shortest time, lowest cost, and highest durability. After each group presented, the best possible bridge type was selected.

The third lesson plan was a ratio-related activity. The lesson began with the question of whether the participants could make paper airplanes and a website was shown with many types of paper airplanes. This website included information about paper airplane models' names, speed, flight time, distance, and ease of construction. The students discussed creating different variations of paper airplanes. Then, images from the furthest paper airplane competition were shared, and the video of the winning paper airplane was watched. The paper airplane's impressive flight distance was an intriguing introduction, prompting participants to contemplate the variables influencing its speed. In the main activity, the class was divided into three groups, and each group was given activity sheets. In addition, the groups were given papers of various sizes and weights and instructions on making an airplane with paper. Each group was asked to generate a hypothesis (i.e., a lighter paper airplane travels longer distances). Then, the groups were expected to test their hypotheses.

The last lesson plan aimed to collect and interpret data in daily life. It was aimed at discovering that the numbers given in statistics have a counterpart in daily life. The lesson began by talking about favorite snacks. Participants named their favorite dishes and snacks. Next, they inquired about their awareness of their daily calorie intake and how closely they paid attention to the nutritional values listed on the back of snacks. They were asked to open a website where they could find the nutritional value of foods. Using this website, they were expected to search their favorite foods' nutritional values (calories, fat, sodium, carbohydrates, protein) and write them in the table. After the groups finished collecting data and filling in the table, they found the mode, median, mean, and range and interpreted their collected data.

Data Collection Tools

The researchers developed a semi-structured interview form as a data collection tool. The questions in the instrument were checked by taking expert opinions. The first interview included eight questions to gain insight into the participants' knowledge of STEM education and their thoughts on preparing a STEM lesson plan. The first interview consisted of questions about the definition of STEM education, the importance of STEM education, the aim of STEM education, and STEM lesson planning. The second interview was conducted during the lesson planning process after the STEM education application. It included nine questions related to the change in their views. In this interview, the lesson plan preparation experiences were questioned, and the challenges experienced and expectations about the lesson were questioned in detail. The last interview was conducted after participants presented their STEM lesson plans in the middle school where they were doing their internship. The purpose was to gather their experiences regarding whether the lesson met their expectations, any difficulties they encountered, and any changes they would like to make.

The interviews were conducted online via Zoom Meeting Application. With the permission of the participants, the interviews were recorded. Each interview lasted approximately 10-15 minutes, and each participant was interviewed for a total of approximately 30-40 minutes. After the individual interviews, pre-service teachers were asked to prepare a STEM lesson plan. Participants developed their STEM lesson plans through microteaching in the practice teaching course before presenting their lessons at their internship school. With the participants' permission, the lesson plans were recorded during microteaching.

Data Analysis

Each participant's STEM lesson plans and the microteaching videos were analyzed according to the conceptual framework of integrated STEM education (Kelley & Knowles, 2016; Roehrig et al., 2021). The common characteristics in the two articles on the conceptual framework of integrated STEM education were selected for analysis in this study. Seven characteristics of the framework used in this study are explained in detail below.

Focus on Real-World Problems

For a lesson plan to be STEM education, it must consist of a real-world problem (Kelley & Knowles, 2016; Roehrig et al., 2021). Choosing a real-world problem is challenging because numerous variables impact students' outcomes. Moreover, the problem statement should be inclusive and engaging for all students (Roehrig et al., 2021). If the data included themes related to real-world problems and the use of mathematics in daily life, it was coded as focusing on real-world problems.

Engagement in Engineering Design

Integrating engineering design into the lesson plan allows students to develop systematic problem-solving skills in situations they may encounter in STEM fields (Kelley & Knowles, 2016). Teachers must ensure students get the chance to assess their designs and redesign using the information gathered. Cost, materials, functionality, and social and political aspects should all be considered while making design decisions (Roehrig et al., 2021). According to Kelley and Knowles (2016), a STEM lesson plan includes a problem that requires an engineering solution to integrate engineering design. Furthermore, students should identify the criteria and constraints and collect, analyze, and interpret data. Moreover, the problem statement should be inclusive and engaging for all students (Roehrig et al., 2021). If the data included themes related to engineering, creativity, optimizing, and modeling, it was coded as focusing on engagement in engineering design.

Scientific Inquiry

Students learn how to ask questions, create hypotheses, and conduct studies using the accepted scientific methods through scientific inquiry, which trains them to think and act like scientists. When given the chance to create their questions about the science topic in the lesson, students start to research the connections between disciplines and take control of their own learning

(Kelley & Knowles, 2016). If the data included themes related to sciences, conjectures, hypotheses, and inquiry, it was coded as focusing on scientific inquiry.

Technology Use in STEM Lessons

In the STEM lesson plan, technology should be conceived as a tool that positively impacts culture, society, politics, economy, and the environment. Teachers should allow students to consider technology critically, helping them become technologically literate. Also, problemsolving should be facilitated by using technology (Kelley & Knowles, 2016). If the data included themes related to technology, such as using GeoGebra, online materials, smart boards, and watching informative videos, it was coded as focusing on technology use.

Mathematical Thinking

STEM education provides students opportunity to understand how mathematics relates to their daily life, this way students' interest and success in mathematics may increase. Students should make sense of the mathematical problem and think about its solution. In a STEM lesson, students need to explain the meaning of a problem and look for entry points to a solution (Kelley & Knowles, 2016). If the data included themes related to understanding mathematical ideas, making sense of mathematics, and connecting with previous topics, it was coded as focusing on mathematical thinking.

Content Integration

Making connections between disciplines and between contexts is crucial to integration. Also, disciplines should be evident to students. To help students understand these linkages, teachers must use interdisciplinary models and representations and engage in deliberate facilitation and questioning (Roehrig et al., 2021). If the data included themes related to interdisciplinary connection, integration of four disciplines, and interdisciplinary transition, it was coded as focusing on content integration.

Twenty-First Century Skills and STEM Careers

Teachers should design small group activities to foster 21st-century skills like collaboration, critical thinking, analysis, and assessment. Teachers also need to carefully facilitate small group work to encourage equal engagement from all students. Students must be given clear instructions on working in small groups to develop 21st-century skills while problem-solving with design thinking (Roehrig et al., 2021). If the data included themes related to twentyfirstcentury skills such as collaboration and critical thinking, it was coded as focusing on twentyfirst-century skills and STEM careers.

RESULTS

The findings of the three participants are presented independently of each other. The comparison of the findings obtained from the participants is presented in the discussion section.

The Case of Robert

Focus on Real World Problems

The lesson plan Robert prepared and implemented was for 6th-grade students. Robert's lesson aimed to integrate the shapes that students have learned to measure area into a real-world problem. In the introduction, Robert reminded the students of the types of thermal insulation that they had learned in the science lesson. Then, the aim was to attract students' attention by giving an example of an endangered bird. Before the main activity, Robert reminded the students how to find the area of a square, rectangle, triangle, and parallelogram because they would use the area of a square, rectangle, triangle, and parallelogram while building the birdhouse. Therefore, the properties and area relationships of these shapes were repeated. Robert showed a video about the birdhouse to move on to the main activity. In this problem, the students were expected to design a birdhouse using sticks and play dough brought by the teacher. For the birdhouse design, the students worked in groups and were expected to use at least two geometric shapes they had learned before. Then, they chose the materials for the birdhouses they had designed. They were expected to make this choice according to the criteria given on the activity sheet. At the end of the lesson, each group presented their birdhouse design and material selection.

Robert's lesson plan started by talking about birds. He asked the students if they kept birds and what they thought about the living conditions of birds outside. To increase students' attention to the lesson, Robert showed videos about birdhouses and started the lesson with an exciting story about keeping the birds that live outside warm.

Based on the story, the kid in the story shared his thoughts with his father and told him that he wanted to build a birdhouse. He also wanted to provide thermal insulation for the birdhouse and do it in the least cost and best way. The father suggested that his son build it thinking about the shapes he learned at school and asked him to calculate the cost. They also talked about endangered birds such as shearwater birds. As seen, Robert used the story about birds, and there was a real-world problem that needed an engineering design. In addition, before this problem, showing videos and talking about birds caught students' attention. Moreover, the problem had two criteria: 'the least cost' and 'the best way.' By looking at these criteria required in the problem, there was no single solution, so students were supported to find different solutions.

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There were multiple birdhouse designs. Robert's lesson plan consisted of a real-world problem that encouraged all students and had multiple solutions.

Engagement in Engineering Design

In the main activity, the students were expected to design a birdhouse. However, there were some criteria for this design process. The birdhouse skeleton must have contained at least two shapes they learned in the previous lesson: square, rectangle, triangle, and parallelogram. The birdhouse must be environmentally friendly, cost-effective, and aesthetic. The students were expected to consider these criteria when presenting their design. Thus, the students considered the cost, function, and aesthetics while designing their birdhouse, which was an engineeringlevel thinking process (see Figure 2). Also, the students could use sticks and playdough for the design model; they could create a design, analyze it, and redesign it. Thus, Robert's lesson plan consisted of an engineering design.

Insulation Material	Cost	Environmental Friendliness	Flammability	Cost
Plastic Foam 	low	harmful	burns easily	10 TL
Wood 	medium	harmless	burns easily	15 TL
Rock Wool 	low	harmless	fireproof	10 TL
Glass Wool 	low	harmless	hard to burn	10 TL
Silicone Wool 	very low	harmless	hard to burn	5 TL

Figure 2. Birdhouse Material Table in Robert's STEM lesson plan: insulation material, cost, environmental friendliness, combustion characteristics.

With this real-world problem and engineering design, students were expected to develop STEM skills. Robert stated that he had difficulty choosing the materials for engineering design. In the microteaching, he asked for feedback on whether spaghetti pasta was the right decision as a material. Robert thought of play dough for the spaghetti pasta's connection points. Styrofoam was suggested as a material, but as it might be a complex material to obtain, it was eliminated. At the end of the discussion about materials used in the activity, it was decided that wooden sticks and play dough were appropriate as wooden sticks were more solid. During the discussion of the problem, one group explained their model as follows:

"We thought of the birdhouse as a pyramid. Since the area of the triangle would be less than the square, we wanted to reduce the cost by cutting the area. So, we made the side parts triangular and the base square."

Many groups used two or three geometric shapes during the birdhouse construction. Therefore, it was decided in the class discussion that using all the geometric shapes students had learned would be challenging. Therefore, it was decided to limit the engineering design criteria to using at least two geometric shapes.

Another group presented their design and defended their material choose.

'When choosing materials, we first looked at whether they harmed the environment and eliminated plastic. We also eliminated wood for the exterior because of the risk of burning. We were undecided between silicone wool and rock wool, but we decided silicone wool was better since it costed the least. If we were going to choose thermal insulation material for the exterior, we thought that by making the inside wooden and outside silicone, we could provide two-sided insulation and eliminate the risk of burning.'

In summary, although Robert successfully integrated engineering design into his lesson plan, he stated that he had the most difficulties in this discipline while preparing his lesson plan. However, looking at the lesson plan, we can say that Robert applied the engineering design criterion in the lesson plan.

Scientific Inquiry

In a STEM lesson, students need to think like a real-life scientist. They should ask questions, create a hypothesis, and test this hypothesis. The students designed a model in Robert's lesson plan; however, it was questionable whether they used scientific inquiry since students did not create a hypothesis and collect data. On the other hand, thermal isolation was the main reason for designing the birdhouse. Robert initiated the lesson by introducing a topic that students had previously covered in their science class: thermal insulation. By incorporating a subject from science into the mathematics class, he encouraged students to consider the interconnections between different disciplines. In microteaching, Robert informed his classmates about thermal insulation. He asked where we use thermal insulation in daily life, the importance of thermal insulation, and the benefits of thermal insulation. Next, he explained that in a house with thermal insulation, there would be no extra costs for heating by stating that: 'Thermal insulation prevents energy loss when we consider the heating in houses, the prices paid to reduce thanks to thermal insulation.'

In addition, for the choice of bird, Robert suggested that it would be nice to choose an endangered bird species and, at the same time, gave information about endangered animals, which was another topic in science education. In summary, Robert thought it was easy to establish the relationship between science and mathematics and successfully integrated science into his STEM lesson plan. However, the lesson plan needed to generate hypotheses by collecting and analyzing data.

Technology Use in STEM Lessons

In Robert's lesson plan, technology was used as a tool. For example, he used a smart board to show PowerPoint slides and videos about birds to catch students' attention. He started the lesson by showing two exciting videos related to birdhouses. He used the smart board only to show the videos. In addition, Robert continued the lesson with a PowerPoint presentation on the smart board. Robert's use of a pre-prepared presentation rather than a traditional whiteboard demonstrates the ease of incorporating technology into teaching mathematics. However, it is worth noting that while technology was used as a teaching tool, it did not necessarily engage students in active learning or encourage them to use technology in their learning processes. Since the students did not use technological tools themselves and saw that Robert needed to make more use of technological materials during the lesson, it can be concluded that the lesson plan needed to be revised to develop technological literacy. He did not use any interactive tools in his lesson plan. Thus, more technology integration was needed in Robert's lesson plan, although he said that technology integration was essential.

Mathematical Thinking

Based on the story given in the lesson, the birdhouse needed to have a low cost. To calculate the cost, the students needed to find the area of the birdhouse they designed. Students used the rulers to calculate the area of the exterior of the skeleton they designed (i.e. the surface area of the birdhouse). After calculating the surface area, students needed to calculate the cost of the insulation material they had chosen, using the prices given per.

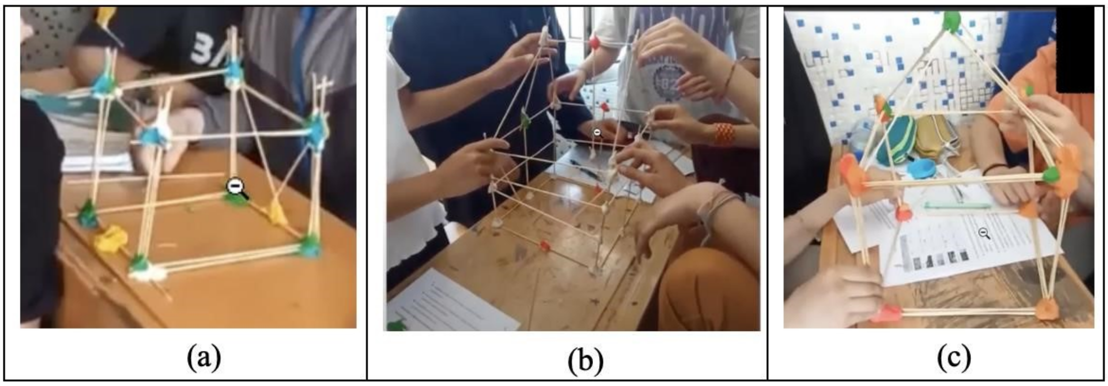

Figure 3. Birdhouses designed by 6th grade students.

The students were expected to calculate the area of the exterior of the skeleton designed using a ruler. They measured the side lengths of the exterior of the birdhouse they designed with a ruler and calculated the area of the shapes they used with the values they found. After calculating their areas, they were expected to calculate the cost of the insulation material they had chosen, using the prices given per $1cm^2$. Cost of silicone: $1cm^2$=5 TL, Glass wool, Rock wool, and Plastic cost: $1cm^2$=10 TL, Wood cost: $1cm^2$= 15 TL. The students made mathematical area calculations with the measurements of their designs and calculated the cost. Since the answers varied based on students' unique designs, they encountered multiple instances of area calculation. The complexity of this problem necessitated a precise application of mathematics. In alignment with the lesson's objectives, students engaged in problem-solving that specifically involved finding areas. Robert's approach illustrated his commitment to concretely integrating mathematics into his lessons, fostering an environment where students start questioning the presence of mathematics in other disciplines. According to Robert, as he did not teach a new mathematical objective from scratch, integrating mathematics was easy, and he satisfactorily integrated mathematics into the lesson plan.

Content Integration, 21st Century Skills and STEM Careers

When we examined the four disciplines individually in Robert's lesson plan, although technology integration was weak, science, mathematics, and engineering were presented to students. Also, the connection between these three disciplines was handled smoothly. Furthermore, STEM lesson plans must be prepared to develop students' 21st-century skills. To achieve this improvement, the STEM lesson plan should include small group work. Robert preferred group work in the lesson plan. In Robert's lesson plan, group work was written as follows:

"The teacher will divide the students into four groups and distribute sticks and play dough. Then, the students will be asked to create a skeleton of a birdhouse, considering the criteria. The students will be given five minutes to think about the birdhouse skeleton, and if they wish, they can take out paper and draw their design. They will be given twenty minutes to make their designs and calculate the areas of the shapes they use and their costs. While the students make their designs, the teacher can walk around, answer the students' questions, and give them the missing materials if the groups still need them. NOTE: The design of the birdhouse is left to the students, and the teacher should not direct the students' designs."

The STEM lesson plan should include a specific occupational group for students to learn about STEM careers. However, Robert did not include a specific STEM occupation in his lesson plan. A specific occupational group could have been mentioned during the problem-solving process, and the students could have been informed about that occupation as one of the STEM careers.

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The Case of Claire

Focus on Real-World Problems

Claire prepared a lesson plan for 7th-grade students. Claire's lesson plan was about the maximum cargo to be loaded on a ship. Claire's main activity started by giving students a reallife problem with a news article about a ship accident. After reading the news article, the students were informed of the main activity. They were asked to imagine themselves as ship captains at the port where the news article accident occurred. They were asked to take the necessary precautions to prevent accidents like this.

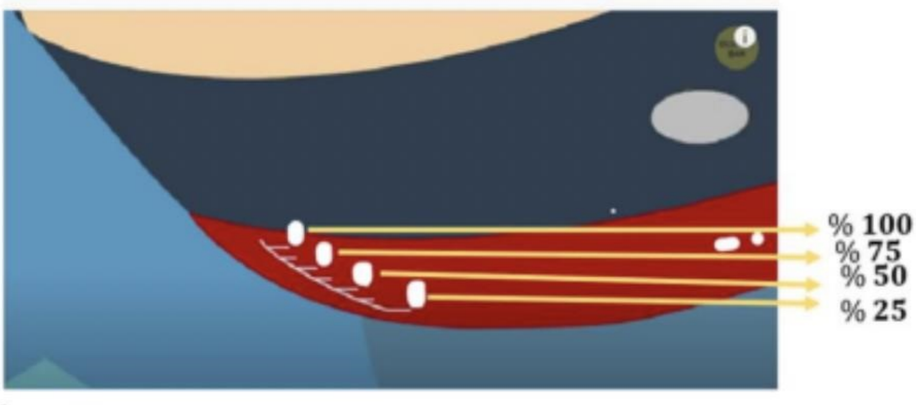

Figure 4. Sinking value of the ship according to the limit line and tons loaded.

Thus, Claire used a mathematics problem that required calculations to address a real-life issue. Her STEM lesson plan involved a real-world problem that encouraged all students and had multiple entry points.

Engagement in Engineering Design

In Claire's lesson plan, no problem situation required students to create a design. Students were expected to fill in the table according to the data and determine the environmental sensitivity of the ship according to the table in Figure 5.

800-900 Barrels	700-800 Barrels	600-700 Barrels
Low environmental sensitivity	**Medium** environmental sensitivity	**High** environmental sensitivity

Figure 5. Environmental sensitivity based on the ship's total fuel consumption.

The problem situation in the main activity did not require students to create a model. Students did not need to test the design and redesign it. Thus, Claire's lesson plan did not meet this criterion. According to Claire, engineering was the most challenging discipline to integrate into a STEM lesson plan. Claire stated that she was more familiar with the science discipline because it had many daily life connections. However, it was challenging for her to integrate engineering because she did not know about it. Claire stated that the engineering terms were high for her, and she had no interest in engineering.

Scientific Inquiry

Students were required to calculate density by applying the ratio of mass to volume, which is a mathematical operation. This illustrates how mathematics is integrated into their science curriculum, where they learn about topics like density. Consequently, introducing a science topic in a mathematics class encouraged students to explore the interconnections between these two disciplines. Claire had the idea of doing the orange experiment (see Figure 6). After showing the experiment and asking students to provide explanations, Claire went on to clarify the experiment and reinforced the concept of density they learned in their science class. She explained: "Due to air pockets within the orange peel, its overall density is lower. This lower density allows the unpeeled orange to float because its volume is larger than its mass." Density is the mass of a substance per unit volume. In calculations, density is obtained by dividing the mass of the substance by its volume. If the density of an object is greater than the density of the liquid in which it is placed, the object sinks into the liquid and displaces the liquid by its volume (MoNE, 2023). This approach connected the experiment to the scientific concept of density and helped students understand the relationship between science and mathematics in real-world scenarios.

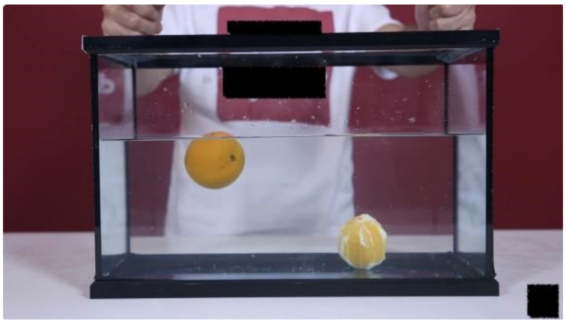

Figure 6. Video of an experiment showing that oranges do not sink with the peel.

After this experiment, Claire discussed why ships did not sink and created a discussion environment in the class. To transition into the main activity, Claire introduced the concept of the red line under the ships and explained how it relates to density. This approach encouraged students to consider the factors that affect density and set the stage for the upcoming activity: "When the weight of ships is light compared to their volume, their density is below one. In this way, they do not sink. A line under the ships shows the maximum amount that can be loaded. Even after this limit, some ships are painted in different colors".

After calculating the total fuel oil requirement of four types of ships, the students were expected to classify their environmental sensitivity. Claire stated that she had a hard time preparing the lesson plan. For example, she had to learn the difference between mass and weight for science integration. She emphasized that teachers should have sufficient knowledge about other disciplines to avoid giving students incorrect information about other disciplines.

Technology Use in STEM Lessons

In Claire's lesson plan, technology was used as a tool. She used a smart board to show PowerPoint slides and videos about an experiment on density and a news article about a sinking ship to catch students' attention. Claire started the lesson by showing an interesting video and news article. She used the smart board to support students with visuals.

Only video was used in the lesson plan for technology integration. Therefore, a simulation of ships sinking as they are loaded was suggested during microteaching. However, Claire did not include such a simulation and questions that support mathematical reasoning in her lesson plan. Even though she did not mention the discipline of technology among the difficulties she experienced while preparing a STEM lesson plan, she used technology superficially. Therefore, the students were not given the chance to develop technological literacy.

Mathematical Thinking

Claire's lesson plan aimed to express the relationship between two multiplicities by examining real-life situations, calculate the quantity corresponding to a given percentage of a given multiplicity, and calculate the whole multiplicity of given quantity. Figure 4 shows that if the ship sinks up to 100% below the limit line, it is carrying the maximum weight it can handle and will sink if loaded any further. Conversely, if the ship is submerged below the limit line of up to 50%, it carries only half of its maximum weight capacity. When the ship's submersion reaches 100%, it indicates that the ship has reached its maximum carrying capacity, and any additional weight will cause it to sink according to the limit line.

SHIP SELECTION CRITERIA	SHIP 1	SHIP 2	SHIP 3	SHIP 4
The Maximum Carrying Capacity of The Ship	…………….	…………….	…………….	…………….
The Amount of Sinking Depending on Tons	For every 9000 tons, 25% of the ship sinks	There are 36000 tons of cargo on board while 40% of the ship is unsinkable	With 39000 tons of cargo on board, 75% of the ship sank.	When loaded at two-fifths of the carrying capacity, the ship has 16000 tons of cargo and 60% of the ship is unsinkable

Figure 7. Table of the maximum carrying capacity of the ship and the amount of sinking depending on tons

The students were expected to find the total carrying capacity of the ship according to the sinking percentage of the ship (see Figure 7). For example, in the second ship scenario, if 40% of the ship is still above water and it carries 36,000 tons of cargo, it means that 60% of the ship has already sunk with that cargo load. Here, the students needed to find the relationship between the sinking percentage and the amount of cargo on board and find the total carrying capacity of the ship. In the first ship scenario, with every 9,000 tons of cargo, if 25% of the ship sinks, the maximum carrying capacity of the first ship is 36,000 tons. This part of the table focuses on finding the total capacity of the ship when a specific percentage of it sinks, which is the main mathematical objective of the lesson plan.

Claire preferred to use the concept of percentages in Figure 4 since percentages are the subject matter. That is, when the ship is loaded, if the limit line of 25% is sunk, the ship carries a weight of 25% of the maximum amount of cargo that can be loaded. The ship can still be loaded up to 75% of its maximum capacity. However, Claire was concerned that the term 100% sinking used in the activity could be confused with the sinking of the entire ship. She defined 100% as when the ship reaches the top of the limit lines at the bottom of the ship. In order to avoid this confusion for the students, she explained the term 100% used in the activity at the beginning of the activity and during group work.

Although Claire had a hard time making mathematics connections in her lesson plan, she included mathematics problems that align with the objectives. The main activity of the lesson was all about percentage problems. Therefore, Claire successfully integrated mathematics into the STEM lesson plan.

Content Integration, Twenty-first Century Skills, and STEM Careers

When we examined the four disciplines one by one in Claire's lesson plan, although technology integration was weak, science and mathematics were clearly presented to students. On the other hand, there was no engineering design in Claire's STEM lesson plan. Considering only mathematics and science disciplines, the connection between these two disciplines was handled smoothly. In the lesson, the students tried to solve a problem involving science using mathematics. This enabled students to see these two disciplines separately and, at the same time, to use them all together. To conclude, Claire successfully integrated two disciplines other than technology and engineering.

STEM lesson plans must be prepared to develop students' 21st-century skills, including collaboration, critical thinking, creativity, analysis, and assessment. She supported students by having each group work as a team, encouraging students who had found the solution to explain it to their peers who were still struggling. In this way, the importance of teamwork was emphasized.

Moreover, Claire asked the students to imagine themselves as ship captains to solve the problem. As a ship captain, the students needed to make appropriate calculations to avoid sinking accidents. There were also issues of fuel consumption and environmental awareness that they needed to think about as captains. In this way, students had a chance to learn about a professional group and solve problems they may encounter in this profession utilizing their STEM skills. Claire's STEM lesson plan cultivated problem-solving and decision-making skills, exemplified by the role of the ship captain. Therefore, it can be said that her lesson plan supported this criterion.

The Case of Sarah

Focus on Real-World Problems

Sarah created a lesson plan for 6th grade students. Sarah's lesson plan began by explaining the working principle of the bicycle. Students needed to understand the gear system of the bicycle in order to find the distance traveled by the bicycle and make the gear selection.

‘When bicycles were first produced, they worked directly on human power. In other words, when we pedaled once, we could only travel as far as the perimeter of the wheel. Simple machines (pulley, gear, etc.) that we use to reduce human effort and make our lives easier appear as gears in the working mechanism of bicycles. With this gear system, we are now able to travel more for perimeter the wheel when pedaling once. The diameter ratios of the cogwheel in the gear system and the ratio of the number teeth on the cogwheel of on them are equal. The ratio of pedaling speed and number of gears directly affects the speed of the bicycle, the energy expended, and the distance traveled. Depending on the slope of the road, the effort spent by the person while pedaling may increase or decrease. The driver can reduce the gear ratio to reduce the effort. The large gear ratio makes it challenging for the driver when going uphill.’

After explaining the working principle of the bicycle and the formula to be used in the problem, Sarah moved on to the real-life problem situation in the activity.

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'A famous bicycle company brings young engineers together with a competition for a new bicycle model to be produced. The company asks engineers to design a bicycle's gear system and wheel structure in accordance with their criteria. The new bicycles they produce must be low in cost and can travel long distances with little effort. It is expected that the bicycle, which has only one gear for an easy use by everyone, will be a product for teenagers and adults. Using the given information in Figure 8, you are expected to answer the following questions. By answering these questions, you will calculate and decide on the wheel diameter and gear ratio of the bicycle. Please consider the criteria the company asks of you and show your work clearly. You must defend your choice.'

Wheel Diameter (cm)	Estimated Production Cost
61 cm	2.140 TL
66 cm	2.560 TL
70 cm	4.370 TL
71 cm	5.130 TL
74 cm	6.260 TL

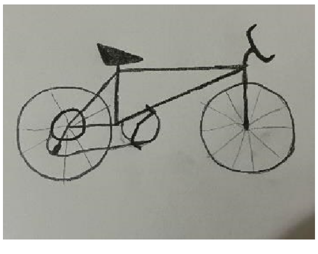
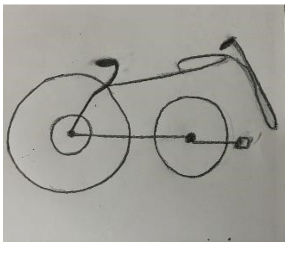
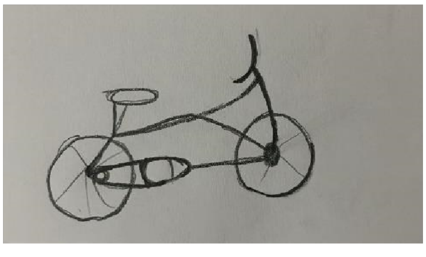
Gear Ratio (Front/Back)
4,82
4,08
3,79
2,65
2,30
1,71
1,47

Figure 8. Wheel diameter of bicycles produced, the estimated production cost and the Gear Ratio table Sarah used in the activity sheet.

As it might be seen, Sarah's lesson plan included a mathematics problem about bicycle design and the working principle of the bicycle. Sarah's STEM lesson plan consisted of a real-world problem that encouraged students with entry points.

Engagement in Engineering Design

Sarah's STEM lesson plan required the students to design a new bicycle. The students were given tables shown in Figure 8. They were expected to consider these tables in their decisionmaking process. Also, the problem required some criteria. The new bicycle must be low in cost and travel long distances with little effort. The students were expected to take these criteria into account when presenting their design. They had to consider the cost and the gear ratio while choosing their bicycle design, which is an engineering level of thinking process. Sarah's lesson plan consisted of an engineering design. With this real-world problem and engineering design, the students were expected to develop STEM skills.

(a) (b) (c)

Figure 9. Bicycle designs of the groups of pre-service teachers during microteaching.

In Sarah's STEM lesson plan for microteaching, she expected from her fellow pre-service teachers to design and draw bicycles for the wheel diameter of their choice. The bicycle drawing allowed the students to show their designs concretely and add art discipline to the lesson plan. However, in light of the feedback received, Sarah decided to remove the bicycle design component from the lesson plan as it would be too time-consuming to make 6th graders draw bicycles and would not leave time for the targeted math objectives.

In the microteaching, a pre-service teacher presented the bicycle design of the first group. They chose the wheel diameter of 61 cm, which was the most appropriate when considering the economic conditions. Also, he mentioned that the price increased a lot when the wheel diameter increased. For example, when the wheel diameter increased by 10 cm, the price tripled. For this reason, 61 cm was the cheapest. In addition, he stated that they chose the middle one in the gear ratio (2.65). He stated that as the gear ratio increased, the force that the rider consumed increased. Therefore, they did not choose the one with the largest gear ratio. A bicycle with the 4.82 gear ratio would be difficult to use. That is why, his group chose 2.65 to be an average value. Their bicycle design was shown in Figure 9 (a).

Another pre-service teacher presented the bicycle design of the second group. They chose a wheel diameter of 66 cm because there was a 5 cm increase from 61 cm to 66 cm and the price only increased by 420 TL. On the other hand, when the wheel diameter was 70 cm, the price almost doubled. According to him, when they considered the ratio, they thought that 66 cm was the most suitable. He stated that they chose the wheel ratio of 2.65 in order not to have difficulty when climbing. He also stated that the ratio of 4.82 would be better for long distance, but they wanted to choose a model for daily use. Their bicycle design is shown in Figure 9 (b). They also designed a windbreak in front of the bicycle.

Finally another student presented the bicycle design of the third group. She stated that her group chose wheel diameter of 66 cm, similar to the second group, because there was not much difference between 66 cm and 61 cm in terms of cost. They thought it was more appropriate to choose 66 cm. Moreover, they chose a gear ratio of 2.30. She stated that since they increased the wheel diameter by 5 cm, they could choose the gear ratio smaller. Their bicycle design is shown in Figure 9 (c).

Sarah stated that she enjoyed thinking about different disciplines together, however it was challenging for her to reduce the activity to the students' level. Sarah prepared an activity to develop critical thinking skills at engineering level. The students were expected to prepare a bicycle model according to the given criteria. This shows that Sarah applied the engineering design criterion in her STEM lesson plan.

Scientific Inquiry

In a STEM lesson, students should think like a real-life scientist. They should ask questions, create a hypothesis, and test this hypothesis. In Sarah's lesson plan, it is questionable whether they made a scientific inquiry since students did not create any hypotheses and collect data. On the other hand, Sarah's lesson plan began with a clear science connection. Sarah started the lesson with the working principle of a bicycle and showed a video about it (see Figure 10). This video was actually about gear wheels, and it explained gear wheels with a bicycle example. Cogwheels are the subject of 8th grade science lesson. Sarah showed the bicycle mechanism that is relevant to her lesson instead of watching the whole cogwheels as students learn simple machines and cogwheels in detail in 8th grade science course.

Sarah thought that this content was appropriate for 6th graders because students encounter simple machines in daily life. In her reflection in the lesson plan, she noted that almost all the students used bicycles and that this topic was of interest to them.

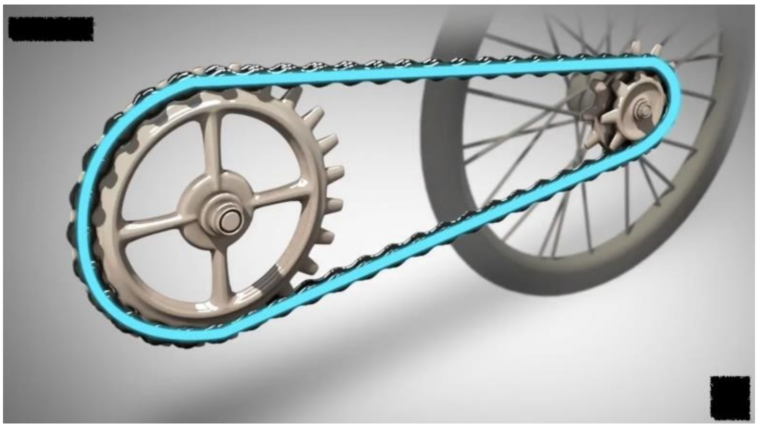


Figure 10. An image from the gear wheels video.

To find the traveled distance a bicycle takes, students needed to use the circumference of the circle they learned in mathematics lesson. In the lesson, students could observe the relationship between mathematics and science discipline. In addition, students discovered mathematical formulas through the guiding questions which were explained in detail in the mathematical thinking section.

Technology Use in STEM Lessons

By using technology as a tool in the STEM lesson plan, students should be taught that technology is a facilitating tool in real life. Also, the teacher should give students the chance to develop technological literacy. In Sarah's lesson plan, technology was used as a tool. She used smart board to show PowerPoint slides and the video about the working principle of a bicycle to catch students' attention and give information about the activity.

There was no video component in Sarah's draft lesson plan. She planned to explain the working principle of the bicycle verbally. However, during the microteaching, she received feedback that the working principle of the bicycle should be understood by the student because it forms the basis of the activity. Therefore, it was thought that the visual effect of this presentation could be enhanced. During the microteaching, Sarah's fellow pre-service teachers searched for an appropriate video. It was decided that the video was necessary and sufficient to understand the subject.

Except for the video Sarah used at the beginning of the lesson, she did not integrate technology into the STEM lesson plan. She did not use technology sufficiently during the lesson. As the students themselves did not use technology, they did not witness teacher's use of technology adequately. In other words, technology was not used to support students' mathematical understanding. Thus, integration of technology was limited.

Mathematical Thinking

Sarah started the lesson with the working principle of bicycle. In this part of the lesson, students needed to understand the effect of the gear diameter ratio and the number of pedaling cycles on the rotation of the wheel because they were expected to design a bicycle based on these variables. Sarah also aimed to help students to discover that the distance traveled on a bicycle is related to the perimeter of a circle. She explained this in the activity sheet as follows: 'At this point, we can discuss the distance traveled as the number of rotations of the wheel times the perimeter of the wheel.'

Sarah's activity sheet included the number of rotations of the wheel:

'The number of rotations of the wheel depends on the number of pedal turns and the ratio of the diameter of the front and rear gears. This means that when we turn the pedal one time, the rear gear and therefore our rear wheel will rotate by this ratio…Depending on the slope of the road, the effort spent by the person while pedaling may increase or decrease. The driver can change the gear ratio by downshifting to reduce the effort. A large gear ratio makes it difficult for the driver when going uphill.'

The students were expected to solve the question given in activity sheet with this information. The number of rotations of the wheel was an equation and the students needed to think about how changes to the variables might affect the equation. This part was important for understanding the variables and the equation. By giving these formulas, Sarah encouraged students to think critically.

The first question in the activity sheet was as follows: 'What does an increase in wheel diameter mean?'. The expected answer to this question was that as the wheel diameter increased, the traveled distance by the wheel increases depended on the diameter. Based on the circumference formula, the distance traveled depended on the diameter of the bicycle. This question aimed to help students to understand the perimeter of circle and establish the relationship between diameter and circumference. Therefore, Sarah reinforced the target objective with this question.

The second question in the activity sheet was as follows: 'What does an increase in the gear ratio mean?'. The expected answer to this question was the greater the gear ratio, the greater the distance the bicycle traveled in one pedal rotation. In the following of the lesson, the students were asked: 'How many pedaling cycles it takes for your bicycle to cover a distance of 500 meter?' With this question, the students were expected to apply the circumference relation they had discovered. Also, each student solved this question for the bicycle of his/her own design. This allowed the students to see more than one solution to a single question and see the features of the bicycle they designed. Sarah established the integration of mathematics in the STEM lesson plan with the questions she added after the bicycle design. Therefore, she supported mathematical thinking in her STEM lesson plan.

Content Integration, Twenty-first Century Skills, and STEM Careers

All disciplines should be clearly visible in the STEM lesson plan and the link between disciplines should be clear. When we examine the four disciplines one by one in Sarah' STEM lesson plan, it can be stated that although technology integration was weak; science, mathematics and engineering were included in the lesson. Also, the connection between these three disciplines was handled. Moreover, in the first version of Sarah's STEM lesson plan, there was a drawing of a bicycle, which Sarah also thought of as an art integration.

In a STEM lesson plan, it's important for the problem to have multiple entry points and solutions so that students can approach it freely. While the teacher can provide guidance, they should refrain from simply telling students how to solve the problem. This encourages students to think critically and problem-solve independently. In Sarah's STEM lesson plan, there was a part for designing a bicycle. The students were expected to design a bicycle. The students could choose one of the options in the table considering their reasoning. In microteaching, three group chose three different designs. Therefore, this part of the activity had more than one solution. At the end of the lesson, the students were required to present their designs with the reasons for their choices. During this presentation, they were required to defend their solutions, which would enable them to develop their multidimensional thinking in the face of problems in their future professions.

Furthermore, STEM lesson plan must be prepared to develop students' 21st century skills such as collaboration, critical thinking, creativity, analysis, and assessment. To achieve this improvement, Sarah included group work in her STEM lesson plan. In the main activity, the students worked in groups of four. Sarah mentioned that she encouraged teamwork among her students by assigning them to work in groups. In this collaborative setting, she also encouraged students who had successfully reached a solution to explain it to their peers who were still working on it. The STEM lesson plan needs to include a specific occupational group for students to learn about STEM careers. In her STEM lesson plan, Sarah asked the students to imagine that they were an engineer and to solve the problem by thinking like an engineer. As an engineer, students needed to make appropriate calculations.

DISCUSSION and CONCLUSION

The development of participants' comprehension and competencies in STEM education was evident throughout the study. Robert initially had an idea about STEM education but acknowledged a lack of sufficient knowledge. Subsequently, after participating in the intervention and preparing a lesson plan, he expressed satisfaction with his participation, highlighting improvements in his STEM knowledge and the ability to design a successful STEM lesson plan. While Claire did not have any knowledge about STEM education at the beginning, at the end of the study she prepared a successful STEM lesson plan and expressed the importance of STEM education for her field. She expressed her intention to incorporate STEM activities into her future lesson plans. In contrast to other participants, Sarah possessed knowledge about STEM education and its significance at the beginning of the study. In the last interview, Sarah not only acquired a general understanding of STEM education but also delved into its origins and underlying purpose.

All three participants in this study added real-world problems to their STEM lesson plans. In addition, all three participants stated that STEM education is a good way to integrate real-life problems into the mathematics lesson so that there is a direct answer to the question of where mathematics is encountered in daily life. Supporting the study of Çorlu et al. (2014), the current study also concluded that STEM education offers opportunities for daily life applications. Furthermore, as Ceylan and Karahan (2021) point out, the real-world problems used by the participants in their STEM lesson plans involve more than one discipline.

Two of the participants (Robert and Sarah) successfully integrated engineering design into their lesson plans. Robert included a model design activity with the use of materials in his lesson plan. Students had the opportunity to test the robustness of their designs. They were also expected to design according to the given criteria. Robert's lesson plan supported that the letter E in STEM education also stands for designing. Similarly, Sarah expected the students to design according to the criteria. Unlike Robert, Sarah did not have a concrete design in her lesson plan. Claire, on the other hand, did not include engineering design in her lesson plan. When the three participants were compared, Robert seemed be the most successful in engineering design. He could integrate engineering successfully into the lesson plan (Maiorca & Mohr-Schroeder, 2020).

In terms of the challenges experienced, all three participants indicated that engineering was the most difficult discipline to integrate into STEM education. As argued by Chai et al. (2020), preservice teachers in this study also found the integration of engineering into STEM lesson plans the most challenging. Especially, Claire stated that she could not integrate engineering to her STEM lesson plan due to her lack of knowledge in the field of engineering which supports the statement of Chai et al. (2020).

All three participants in the study started their STEM lesson plans with science integration. They integrated the topics the students had learned or would learn in the science course. When the challenges experienced were evaluated, two of the participants stated that the integration of science was the easiest. They stated that it was easy to connect science and mathematics because the science course uses mathematics. On the other hand, Claire stated that she had difficulty in science integration. According to Claire, her lack of expertise in the field of science could lead to misconceptions, and she felt the need to have a solid understanding of science before attempting integration. The challenges experienced by Claire support the statement of Nadelson et al. (2012). In addition, as Lawson et al.'s (2021) emphasized Claire also stated that different disciplines need to plan STEM education together.

At the beginning of the study, the participants argued that technology integration was very important for mathematics education and that the use of technology was necessary in our age. However, it was observed that technology integration was weak in all three lesson plans. As for the use of technology, the participants only included videos and presentations on the smart board to their lessons. However, according to McCulloch et al. (2018) the use of smart boards is not sufficient for technology integration in mathematics courses and teachers need to have knowledge about integrating technology into their lessons. This might stem from the fact that, participants did their internship in a public school, they prepared their lesson plans in accordance with the school conditions. For example, Robert wanted to have the students design in a digital environment instead of using sticks and play dough. However, he could not do it because of the conditions at school. Claire and Sarah stated that the students did not used to use technology in lessons. Thus, these situations might have also affected their use of technology (Tondeur et al., 2013).

Before preparing the STEM lesson plan, the participants stated that GeoGebra could be used in the STEM lesson plan. They mentioned the benefits of concretizing abstract concepts, visualizing them and increasing student interest by giving GeoGebra as an example of technology integration similar to Şahin and Kabasakal (2018). On the other hand, none of the participants used GeoGebra in their STEM lesson plans and their technology integration was weak. Although the participants identified GeoGebra as a STEM material, they did not use it in the lesson plans. As Jocius et al. (2021) noted, the participants used the Internet sources as technology integration in their STEM lesson plans. As Chai et al. (2020) stated, it can be concluded that pre-service teachers might be inadequate in integrating technology into their lesson plans due to their insufficient knowledge of technology. Furthermore, the participants' weakness in technology integration supports Jocius et al., (2021)'s argument that pre-service teachers need to master technology skills. Although the participants had positive opinions about the use of GeoGebra in mathematics lessons, they did not use it in their lesson plans. They argued that it would be difficult to apply GeoGebra due to the conditions of public schools. On the other hand, while the participants focused only on technology in designing STEM lesson plans in the first interview, they realized the importance of science and engineering disciplines after the intervention. Therefore, science and engineering integration may have overshadowed technology integration. Thus, the reasons for the lack of technology use in the STEM lesson plans might stem from lack of technology knowledge or focusing more on other disciplines in STEM.

In the current study, the participants successfully integrated mathematics into their STEM lesson plans. They stated that they had difficulties in making mathematics visible in other disciplines during the preparation process. In Sarah's draft STEM lesson plan, mathematics integration was weak. She strengthened the mathematics integration in her lesson plan according to the feedback she received in microteaching. Robert and Claire stated that the transition from other disciplines to mathematics should be set clearly and explicitly. Claire said that she was afraid of getting a reaction from the students that the lesson did not include mathematics. However, similar to Sian Hoon et al. (2022); all participants made a lot of effort to improve themselves in the field of STEM education.

According to the participants in this study, thanks to STEM education, students went beyond the usual mathematics education and thus their thinking about mathematics was positively affected. This result can be considered an example of making mathematics enjoyable, as noted by Tatar et al. (2013), and Sümen and Çalisici (2016). Also, as Anderson et al. (2020) and Bartels et al. (2019) stated, participants argued that STEM education is effective in learning.

All of the participants emphasized the importance of students developing new skills while preparing STEM lesson plans and included group work in their STEM lesson plans. In addition, Sarah and Robert expected the groups to present their designs and defend their answers at the end of the lesson which aimed to develop 21st century skills. This result supports the studies by Wijaya et al. (2022), and Zhang and Zhu (2023). Moreover, two participants included a professional group in their STEM lesson plans. Claire asked the students to imagine that they were a ship captain and Sarah asked the students to imagine that they were engineers. Sahin (2020) also argues that STEM education should offer students the opportunity to recognize professional groups.

An important point of consideration for future research is the need for more in-depth exploration of the specific challenges pre-service teachers face in each discipline when preparing STEM lesson plans. While participants in this study mentioned the disciplines they found most and least challenging, a more comprehensive analysis could yield richer insights. To address this, future studies could employ more detailed questioning or provide specific examples to gather more nuanced data regarding the difficulties encountered in each discipline. Moreover, data collection tools can be developed in future studies. Qualitative research was conducted in this study. Quantitative or mixed studies can be conducted to investigate the challenges pre-service teachers face during the preparation of STEM lesson plans.

DECLARATIONS

Ethical Approval: The research titled "Investigation of Prospective Teachers' Views on STEM Education and the Difficulties Experience in the Lesson Planning Process" was approved by the Middle East Technical University Human Research Ethics Committee on 14 January 2022 with the number 28620816 and protocol number 0018-ODTUİAEK-2022.

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Competing interests: The authors declare that they have no competing interests.

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STEAM Eğitimi Araştırmaları Derneği

Science Teachers' Views on Seasons and Climate Unit

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ABSTRACT

The seasons and climate unit, which is a unit requiring an interdisciplinary approach within the scope of the science course, is covered within the scope of the 8th grade middle school science course according to the recent change in the science curriculum. Within the scope of the study, we aimed to determine science teachers' views on the seasons and climate unit in terms of teacher readiness. Descriptive analysis, one of the qualitative research methods, was preferred in the research process. During the process, semistructured interviews were conducted with 22 volunteer science teachers and the data obtained was coded by two different people. While coding, a process in the target-objective-implementation plane was taken into consideration. As a result of the study, it was concluded that the place of the seasons and climate unit in the curriculum was found appropriate by the teachers, the fact that there were teachers who did not receive any training on this subject during their undergraduate education revealed misconceptions in the teaching of the subject, the subject was understandable by the students, the learning level of the students was tried to increase with modelling and experimentation, and the use of educational materials other than the textbook was emphasized. Findings of the study implicate that focusing on in-service training of teachers will be beneficial for teachers to use different teaching methods and techniques in their lessons.

Keywords: seasons, climate, science, measurement, assessment

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INTRODUCTION

The great civilizations of the world (Indian, Chinese and Mesopotamia) were founded on fertile lands and near water sources. Although ease of transportation and trade are reasons for this, the main reason is the suitability of climatic conditions. Even in today's conditions where technological opportunities are widespread, people prefer areas with favourable climatic conditions. The great scientist Ibn Khaldun's saying "geography is destiny" actually describes the fact that "geography is not destiny, but the future and civilization" (Şahin & Belge, 2016). Landforms, climate characteristics, vegetation, water and soil characteristics are the main natural environment features.

People need to recognize natural environments, shape their daily activities and long-term plans (settlement, transportation, trade, tourism, education, etc.) accordingly, and make this a norm of life. The most permanent way to gain this norm and make people acquire it is through education. Therefore, individuals need to undergo the necessary geography education appropriate for their level from an early age and gain the skills they should have by age. A good geography education helps individuals to adapt to different geographical conditions in the best way and connects individuals to life. The desire of people to recognize the natural environment in which they live, their need for nature and their labour to improve their living conditions by using what they have learned shows how important the science of geography is (Akbaş, 2021). The importance of this science in human life can only be ensured by providing sufficient geography education.

Geography education has been given in all countries in the world and in our country for many years. Especially in the current century, the importance of geography education is increasing even more. Considering the importance of the geopolitical position of our country, the basic level of geography knowledge that our citizens should have increases the importance of geography education even more. Thanks to a good geography education, individuals gain competencies such as recognizing the environment they live in, being aware of the advantages and disadvantages provided by this environment, recognizing environmental problems and producing solutions to these problems (Kaya, 2013).

In Turkey, geography topics are included in life science, social studies and science courses in basic education (Bahar, et al, 2018; Kızılçaoğlu, 2006; MoNE, 2018a, 2018b, 2018c, 2018d). Starting from the 9th grade of secondary education, topics are covered in depth in the geography course (MoNE, 2018d). In addition, science subjects are given to students from the 3rd grade of primary school and include not only physics, chemistry and biology but also geography, metallurgy, meteorology and space sciences. At this point, it is important to train teachers with an interdisciplinary perspective (Çeken, 2020).

The seasons and climate unit in the science curriculum is directly related to the geography course. However, since this subject was not included in previous science programs, it has been revealed in studies that teacher competencies in this subject are limited and misconceptions exist (Özcan et al., 2018; Semercioğlu et al., 2019). This situation is also valid for students, and it has been determined that students prefer to stay within stereotypes, have difficulty in presenting different perspectives, and have misconceptions especially about the position and movements of the Earth in space (Alkış, 2013; Bolat & Altınbaş, 2018; Boz, 2019; Özcan & Birgin, 2021; Özdemir et al., 2010; Sneider et al, 2011). In-depth analysis on these issues will enable the identification of points that need to be corrected, especially in the content and process.

Within the scope of the study, it is aimed to determine the views of science teachers on the seasons and climate unit. The study also has sub-objectives regarding teachers' readiness, the place and appropriateness of the subject in the program, the acquisition of the gains in the process, the misconceptions, appropriateness of textbooks and auxiliary resources and their competencies in terms of measurement and evaluation.

METHOD

Within the scope of the research, qualitative research methods were adopted due to the purpose, the study group and the way the data were collected. Qualitative research is defined as the process of making sense of human-related problems by questioning them with unique methods while taking place in the natural environment of social life (Creswell, 1998). Within the scope of the study, analyses of common experiences and experiences related to a phenomenon were discussed. A phenomenological pattern is a pattern that reveals the common meaning of the lived experiences of several people regarding a phenomenon or a certain concept (Creswell, 2018). In this process, the views of individuals were trialled to be revealed with the phenomenological design, one of the qualitative research methods.

Participants

In the study, 22 volunteer science teachers with different experiences and working in different types of schools were interviewed, with teachers with master's and doctorate degrees in the field of science being prioritized as the study group.

Table 1. Demographic Characteristics of Participants

Seniority Year	**Education level**		
	Bachelor Degree	**Master's Degree**	**PhD**
6-10 years	4	1	2
11-15 years	1	2	2
16-20 years	4	3	1
21 years and over	1	1	

Data Collection and Analysis

According to the literature review conducted within the scope of the study, a semi-structured interview form consisting of 8 questions was developed. The interview form was presented to

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7 experts in the field to ensure content validity and adjustments were made according to the feedback received. While determining the experts, it was prioritised that they had conducted studies in this field. In this context, for example, for question one, after the statement "Have you taken a course related to the "Seasons and Climate" unit during your undergraduate education?", the question was updated by adding the statement "How is the compatibility of this subject content with the courses you have taken?". The final version of the questions in the form is presented below and the purpose of the questions is given.

Table 2. Interview Questions and Objectives

Interview Questions	Target
1. Did you take a course related to the unit "Seasons and Climate" during your undergraduate education? How is the compatibility of this subject content with the courses you have taken?	readiness, level of knowledge
2. Is it appropriate to include the subject of seasons and climate in the 8th grade science curriculum? Why?	Is the outcome and content matching the right grade level and the right course?
3. Do you think that the learning outcomes for this unit are learned sufficiently by the students? Why?	whether the acquisition is sufficiently grasped or not
4. If there are extra practices you did during the unit, write why you chose these practices.	developing and using activities for course content
5. Do you find the textbook sufficient in terms of content etc. for this unit? Why?	compatibility of course materials with learning outcomes
6. Apart from the textbook, do you use digital resources related to this unit? If yes, please write the digital resources you use.	access to different resources
7. Are there any misconceptions you have identified about this unit? If so, write them down.	Determination of misconceptions (If any)
8. Evaluate the appropriateness of the questions related to this unit in the textbook or the auxiliary resources you use, such as the appropriateness of the outcome and the appropriateness for the student.	appropriateness of textbooks and auxiliary resources

After organizing the interview form, interviews were conducted with 22 science teachers. Of these, 7 were interviewed via online platforms and 15 were interviewed face-to-face. The interviews were recorded with the consent of the participant. After data collection, the data obtained from the interviews were coded by 2 different people (researchers). While coding, codes, categories and themes were created by considering a process of operation at the goalobjective-implementation level. For example, for question 2, a teacher answered "I think that the topics related to space and earth should be covered in the science course...". This answer was coded as "topics related to space and earth" and "being related to the subject area". The percentage of agreement between the coding was examined and found to be 92%. In order to determine the compatibility between the codes, the percentage was calculated by dividing the number of common codes by the total number of codes. Agreement above 85% is considered reliable (Miles et al., 2014). The different codings were reviewed by the study team and included in the study according to their suitability. Care was taken to avoid any data loss during the interview process. The data obtained after the coding process were grouped into sub-themes and categories.

FINDINGS

In the research process, the opinions of science teachers regarding their competencies, awareness, relationship with the course, and misconceptions about the subject of seasons and climate were examined.

Question 1

In this question, it was aimed to question the scientific background of the teachers on the subject of seasons and climate. The data obtained in this context are categorized and presented in the table.

Table 3. Science Teachers' Ways of Acquiring Scientific Knowledge on Seasons and Climate

Opinions	f	%
No, I didn't.	15	68
I took an elective environment course.	4	18
I took an elective geography course.	3	14
Total	22	100

When Table 3 is analysed, 68% of the teachers stated that they did not take a course related to this subject content. On the other hand, 18% of them stated that they took an elective environmental course. At this point, teacher 8 stated, *I don't remember taking a course on the seasons and climate unit. We took an environment course. The subject of seasons and climates was mentioned in the environment course, but as I said, we did not take it as a separate course. The content of the subject was superficial and there was no in-depth explanation.* From this statement, it comes to the forefront that the information received within the scope of the environment course was limited. Those who dealt with it in detail were those who took elective geography courses. Teacher 4, who responded to this code, said *I took a geography course for one semester. There was a short presentation comparing the climate types in Turkey*, while teacher 1 said *We took it as an elective course, the content at the university was more detailed.* This situation shows that there is no consistency in conveying the scientific dimension of the content. In addition, the study revealed that it was determined that the teachers who took the elective geography course were mostly educated in well-established universities. At this point, increasing the variety of courses to be chosen offers individuals the opportunity to develop themselves in different fields.

Question 2

Within the scope of this question, data on the compatibility between the subject and the curriculum were trialled to be obtained. The data obtained were categorized and presented in Table 4.

Table 4. Science Teachers' Opinions on the Place of Seasons and Climate in the Curriculum

Opinions	f	%
Suitable	17	77
Not Applicable	5	23

77% of the science teachers in the study group stated that this topic is appropriate for the 8th grade science curriculum. When the opinions of the participants who used the expression "not suitable" were analysed, all of them stated that this topic should be taught in the social studies course. Teacher 19 stated that *This subject is not suitable for the principle of spirally in the curriculum. In the social studies curriculum, students currently see climate and climate change etc. in grades 5-6 and 7. When they reach 8th grade, we cover climate and weather events in science. I think it is appropriate to teach it in the social studies course.* When the opinions of the teachers who say it is appropriate are analysed, 40% of them state that it should be handled in a spiral structure in the context of space and the world subject area. Teacher 5 stated that "since space and celestial bodies are included in the subject of science, the movements of the planet earth and the results caused by these movements should be in the science program". Teachers 6, 7 and 8 stated that these subjects are related to the subjects in the lower grades in science. Teachers 12 and 14 emphasized that these topics have an interdisciplinary dimension. Teacher 22 also stated that it has an impact on science literacy.

Question 3

In the third question, it was trialled to obtain data on the learning of the subject by the students. The data obtained were categorized and presented in Table 5.

Table 5. Science Teachers' Opinions on the Adequate Learning of the Acquisitions in the Unit

Opinions	N(f)	%	Sub Views	f	%
Yes, they are learning.	13	59	Their readiness is adequate	3	23
			Relevance to daily life is effective	3	23
			Interest in the lesson	4	31
			National Exam will also be released	3	23
No they cannot learn.	9	41	Past learning is insufficient	2	28,6
			Abstract content	3	42,8
			Outcomes are not clear and unambiguous	2	28,6

When Table 5 is analysed, 59% of the teachers stated that students did not have difficulty in learning this subject. 41% of the teachers stated that students could not learn this subject or had difficulty in learning it. When the reasons for this situation are analysed, it is seen that 7 different opinions come to the fore. Of these, the most common view was that there was interest in the lesson. Teacher 5 stated that *...I understand from the results of the exams and the dialogues in the classroom environment that every student who shows enough interest in the lessons has no difficulty in learning this unit.* In addition, readiness, being related to daily life and the fact that it will be on the central exam applied within the scope of the High School Transition System (National Exam) are the opinions stated to be effective in learning. The most frequently cited reason for not learning is that it contains abstract content. Teacher 2 stated that ... *the subject should be fully learned in the 5th and 6th grades. If it is not learned well in those years, the part in 8th grade remains abstract. Unfortunately, the student cannot learn at the expected level.* In addition, Teacher 22 stated that there is a problem in limiting the learning content by using the expression "*since the outcomes are not clear and precise, it causes different learning on the basis of class and teacher*".

Question 4

In the fourth question, it was trialled to obtain data on the extra practices of the teachers on the subject. The data obtained were categorized and presented in Table 6.

Table 6. Extra Practices Performed by Science Teachers

Opinions	f	%
Watch videos	5	20,8
I show animations	6	25
I conduct experiments and modelling studies	11	45,8
I commission projects	1	4,16
I'll make you do drama	1	4,16
Total	**24**	**100**

When Table 6 is examined, the majority of the opinions focused on experimentation and modelling. Teacher 2 stated *Especially in experiments, I try to make the angle of fall of light visual and concrete....* Experiments and modelling studies allow students to concretize. Other opinions focus on video and animation.

Question 5

In the fifth question, it was trialled to obtain data on the adequacy of the textbook on this subject. The data obtained were categorized and presented in Table 7.

Table 7. Teachers' Opinions on the Adequacy of Science Textbooks in the Scope of Subject Matter

Opinions	f	%
Sufficient for the curriculum	9	34,6
Related experiments should be increased	2	7,7
The subject is explained superficially	9	34,6
Measurement and evaluation practices are not sufficient	3	11,5
It will be enough if the activities are organized in the book	3	11,5
Total	**26**	**100**

When Table 7 is analysed, it is seen that teachers' opinions are grouped under 5 main headings. Among these, Teacher 14 stated *There is sufficient level of expression because the limitations are clear* and Teacher 19 stated *I think the textbooks are sufficient in terms of achievements*. At this point, it is stated that the curriculum has limitations. The most frequently expressed opinion is that the subject content is superficial. Teacher 17 said, *It should elaborate the information content a little more* and Teacher 3 said, *I do not find the textbook sufficient at all*. It is understood that it can be used when improvements are made in the content. Teacher 21 used the expression *experimental applications are insufficient*. Some of the opinions of the teachers (13.6%) were that measurement and evaluation practices were not sufficient. Teacher 16 stated that "the *number of questions in the book should be increased*".

Question 6

In the sixth question, it was trialled to obtain data on digital content on this subject. The data obtained are categorized and presented in Table 8.

Table 8. Teachers' Views on Digital Resources Other Than Textbooks

Opinions	f	%
I use the Education Information Network (EBA)	15	41,7
I use the resources of specialized publications	11	30,6
I use Youtube	4	11,1
I use self-prepared resources	5	13,9
I use Social Media	1	2,8
Total	**36**	**100**

When Table 8 is examined, it is determined that most of the opinions obtained from the teachers use EBA as a digital platform. Teacher 4 stated *I especially use EBA and YouTube*. As can be understood from this statement, teachers use multiple platforms together. This can be considered normal due to the structure of digital content. Teacher 9 used the statement *I use the course presentations I prepared myself and the EBA platform*. At this point, she states that the presentations and contents she prepared are effective. Teacher 21 said, *EBA and youtube videos are sufficient. However, misconceptions are very common in youtube videos.* From this point of view, she states that platforms that are not examined facilitate learning but also cause wrong teachers.

Question 7

The seventh question includes data on the misconceptions identified by the teachers about the subject. The data obtained are categorized and presented in Table 9.

Table 9. Teachers' Opinions on Misconceptions Related to the Subject

Opinions	f	%
No misconceptions occur	10	37
The concepts of rotation and entanglement are confused	3	11,1
The concept of enlightenment zone is confused	3	11,1
There is confusion with the angle of incidence of the rays	5	18,5
Misconceptions about precipitation types can occur	3	11,1
The concepts of weather events and climate are confused	3	11,1
Total	**27**	**100**

When the teachers' views on misconceptions are examined in Table 9, 10 teachers stated that no misconceptions occurred. Seven of the teachers who expressed these views are undergraduate graduates. Considering that they did not take these courses in undergraduate education, it can be said that they had difficulty in identifying misconceptions. Teacher 22 stated *They think that the sun's rays can fall everywhere at right angles*. Teacher 21 stated *They confuse weather events with climate. Since the unit is mostly at the comprehension and application level, students need to learn a lot of concepts, and there are problems in using high-level mental skills. For this reason, it would be appropriate to deal with the unit by breaking it down in lower grades.*" From this point of view, it is emphasized that the most important reason for misconceptions is insufficient lower learning.

Misconceptions and misconceptions are some of the biggest obstacles to correct learning. In addition to preventing correct learning, misconceptions and misconceptions are more difficult to correct than teaching the subject from scratch. One of the most important factors in preventing such mislearning is that the teacher's knowledge of the subject area should be very solid.

In the subject of seasons and climate, teachers' undergraduate education is very different (undergraduate graduation in different years) and teachers' desire and attempts to update their field competencies differ from each other. This situation causes misconceptions and confusion. In the study, it was seen that approximately 37% of the teachers stated that no misconceptions occurred, while the rest stated that misconceptions and confusion occurred in some subjects.

Question 8

In the eighth question, data were obtained on the appropriateness of the questions related to this subject in textbooks or auxiliary resources to the objectives and the appropriateness for the student. The data obtained were categorized and presented in Table 10.

Table 10. Teachers' Opinions on the Appropriateness of Questions in Textbooks or Auxiliary Resources

Opinions	f	%
The assessment questions in the textbook are very superficial.	6	16,7
The assessment questions in the supplementary resources contain very deep and complex information.	8	22,2
Not sufficient in terms of measurement in EBA	2	5,6
Publishers' questions are incorrect or not in line with the learning outcomes	11	30,6
Questions in the textbooks are appropriate to the level of the student	9	25,0
Total	**36**	**100**

When Table 10 is examined, the most frequently stated opinion is that the questions of the publishing house are incorrect and not suitable for the learning outcomes. Teacher 7 stated *There are questions outside the curriculum in supplementary resources*. Teacher 16 stated, *The questions in the textbook are appropriate for the learning outcomes.* When the situation is analysed in general, it is an important problem that the questions of the publishing houses are not suitable for the learning outcomes and contain meta-knowledge. On the other hand, the view that the questions in the textbook are in line with the learning outcomes comes to the fore, but a group expressed that they are superficial. This situation creates an inconsistency. Teacher 16 said, *The questions in the textbook are in line with the learning outcomes. However, in the question banks that our students use for National Exam preparation, there may be questions outside the objectives.* At this point, the existence of an exam such as National Exam creates this situation.

At the end of the interview, teachers were asked about their willingness to receive training on this subject. Fifteen of the teachers said yes and seven said no. It can be said that teachers are willing on this issue. Teacher 7 used the expression "*I would like to improve myself when the content and time are adjusted*". The fact that teachers are open to innovations is also an important factor at this point.

CONCLUSION AND DISCUSSION

Science teaching has been renewed by changing and developing according to the conditions of the time from the past to the present. In this process, previously prepared programs and books aim to eliminate systematic errors and achieve perfection by taking into account the feedback received in the process. Many studies have been conducted on the examination of curricula and textbooks (Doğan et al., 2020; Karamustafaoğlu et al., 2016; Özcan et al., 2018; Yıldız Yılmaz & Tabacu, 2017). In these studies, there are contents for the development of curricula and textbooks. Within the scope of the study, it was tried to answer the research questions according to the data obtained in the context of examining the seasons and climate unit, which is among the contents of the 8th grade of the science curriculum, according to teacher opinions. At this point, the findings for each question were discussed and compared with the literature.

Since the seniority years of the teachers currently working in the Ministry of National Education generally vary between 1-45 years, the graduation status of the current teachers (teacher high school, associate degree, education institute, bachelor's degree), the curriculum, course contents, knowledge, skills and field infrastructure they have vary (Bilir, 2011). It was determined that 68% of the teachers participating in the study did not receive any undergraduate education on seasons and climate. It was seen that the fields were on environment and geography within the scope of elective courses. At this point, increasing the variety of elective courses can contribute to the development of individuals. It was concluded that teachers who could not improve themselves at this point in undergraduate education overcome their deficiencies by using personal development methods. When the studies on teachers' field and personal development are examined in the literature, it is seen that some teachers who have postgraduate education constantly improve themselves (in-service training, seminars, courses, etc.), while some teachers are closed to innovation and development (Altun & Sarpkaya, 2021; Eroğlu & Özbek, 2020; İnandı & Gılıç, 2020). In this context, before making changes in the curricula, it should be ensured that teachers' readiness regarding the subjects covering these changes is determined and that they receive training related to the subject area when necessary. In their study, Tekbıyık and Akdeniz (2008) found that no matter how willing teachers are to cope with changing curricula, they experience problems as a result of not knowing the curriculum. In addition, Kahramanoğlu (2019) found that teachers' curriculum literacy was at a medium level. In addition, there are studies on the inadequacy of curriculum introductions (Özcan et al., 2018; Ural Keleş, 2018). These results support the findings obtained from the study. Changes should be made after teachers are made ready for the curriculum changes. Otherwise, expecting teachers to adapt themselves to the changes made after the curriculum is changed leads to the formation of different levels among teachers regarding subject areas. As a result, providing the skills and infrastructure that need to be acquired as a result of the changes in the curriculum should not be left to the teachers' own initiative and a process-oriented solution should be followed.

Another topic addressed within the scope of the research is the efficiency and appropriateness of the books and existing content. At this point, as in the literature, the fact that the science course is more suitable for experiments, videos, animations, projects, etc. has been revealed in studies (Öztanrıkulu, 2020; Saklan & Ünal, 2019; Kapucu, 2014). It was determined that the majority of teachers generally focused on experiments and modeling studies in teaching the subject and increasing its retention, followed by animations and videos. In this context, the primary resources for teachers in teaching and retaining the subjects are the curriculum and textbooks. In the study, it is seen that the majority of teachers find the curriculum sufficient in terms of subject matter, but they state that the subject matter is covered superficially in the textbooks. This situation is thought to be directly related to the National Exam. The fact that the subject is close to the Geography course in terms of content and that science teachers did not receive training on seasons and climate in their undergraduate education or received limited training reveals the view that teachers do not have in-depth knowledge in this field. When the studies in the literature are examined, there are findings that the subject is not given in depth on both activity and subject basis (Bayır & Kahveci, 2021; Erdoğan & Azizoğlu, 2022; Kahveci & Bayır, 2020; Şantaş, 2017). At this point, Erdoğan and Azizoğlu (2022) stated that life-based learning activities are very few in textbooks. Textbooks and their content should be strengthened digitally in line with the changing needs in line with the requirements of the age and offer alternative options by taking individual differences into consideration. When the results of the research are examined, it is seen that the majority of teachers prefer Education İnformation Network (EBA), which is enriched with digital content prepared by the MoNE and made available to teachers and students, as a digital resource other than textbooks. It was also found that a significant number of teachers preferred the resources prepared by private publications and the digital contents of these resources in addition to the textbook, some of them prepared the digital contents themselves, and some of them used social media environments. In the literature, it is seen that the most preferred digital resource of teachers is EBA (Aydınözü et al., 2016; Geçici, 2022; Yılmaz & Laçin Şimşek, 2017). It can be said that one of the most important reasons for this situation is controllability. At this point, it is seen that the use of digital content has become more widespread after the pandemic (Filiz & Gökmen, 2022; Yılmaz & Toker, 2022).

In the evaluation of the teaching of a subject, it is very important to identify misconceptions and to handle the process objectively in order to support the development of individuals. When the results are analyzed, it is seen that the teachers generally stated that the questions in the book were not directly related to the learning outcomes but remained superficial (at the recall-concept level). In his study, Genç (2020) stated that the assessment and evaluation practices in 8th grade textbooks did not include the competencies for PISA (Programme for International Student Assessment) at the desired level and that the content remained mostly at the level of comprehension. Yücel and Karamustafaoğlu (2020) stated in their study that the most frequently mentioned negative point about the textbooks was the assessment and evaluation activities. This situation is also seen in the study conducted by Köse (2021), and the study supports similar findings. In addition, the motivation of students due to the National Exam (High School Transition System) exam puts private publishing houses in a race and leads to out-ofachievement questions. This process in schools is not very healthy in terms of measurement. However, the sample questions published monthly by the Ministry of National Education serve as a guide for both students and teachers. In addition, in the interviews with the teachers participating in the study, they stated that there were misconceptions or confusion in the teaching of the subject (63%). At this point, it was seen that they learned the information especially at the level of recall and comprehension, but they had difficulty in the content related to high-level skills. At this point, the fact that teachers' field competencies are weak leads to the result that their motivation towards the lesson and the subject matter are not sufficiently understood by the students. This situation is similar to the result obtained by Sürücü and Ünal

(2018) in their study that motivation and interest in the course increases when the teacher does what he/she does in line with his/her interests and abilities and decreases in the opposite case. It is also consistent with the result of Ecevit and Şimşek (2017) that teachers have difficulty in identifying misconceptions. It has been determined in the studies in the literature that misconceptions are frequently seen in pre-service teachers who are trained in this field, especially in climate, wind, temperature and precipitation-based subjects (Pınar & Akdağ, 2012; Turan, 2006). This situation will be similar for teachers who do not take any course. As a result, as a result of the interviews with teachers, the study revealed that the content of textbooks should be improved. In addition, it is also important to increase teacher competencies.

In line with these results, the following recommendations are presented:

- Since the majority of teachers graduated from academic programs whose content has changed over the years, they have different competencies in some field subjects. In order to overcome this situation, in-service trainings should be given to teachers at certain time intervals.
- Reconsidering the limitations of the gains in a clearer and more understandable way and enriching the course materials with concrete content will contribute to the teaching of the subject.
- Teachers should focus on interactive activities such as experiments, modelling, animations and videos in order to increase comprehension.
- It is thought that it would be appropriate to enrich the textbooks in a way that does not require the use of special publications in terms of measurement and evaluation.
- It would be useful to enrich the lectures with interactive learning methods such as activities, experiments, etc. related to the subjects that students have difficulty in learning and where misconceptions occur more.

Since there is a central exam in National Exam at the grade level, students' use of special publications and auxiliary resources varies. However, since the same curriculum is applied throughout the country, it is thought that it would be appropriate for all supplementary resources to be examined in detail by the Ministry of National Education and to be allowed to be printed after a certain control process.

DECLARATIONS

Ethical Considerations: In this research, the ethics committee approval notification document containing the eligibility decision for the research was received from the Kastamonu University Social Sciences and Humanities Ethic Committee (Date: 09.03.2023, No: 2023/10). All ethical procedures were followed during and after completing the study.

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conducted the data collection process. She is competent in face-to-face interviews. Ç.A. and V.A. were responsible for statistical analysis. They are competent in the use of statistical programs. C.G. and V.A. were involved in the drafting of the article (introduction, discussion and conclusion). The editorial processes were followed by C.G. In addition, the referee feedbacks were handled jointly by the authors and necessary actions were taken.

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Ecocentric and anthropocentric worldviews: Are they incompatible?

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ABSTRACT

The dialectic between ecocentrism and anthropocentrism has become the central discussion around the growing ecological crisis we live and the purpose of environmental education. This study seeks to clarify the compatibility between these two worldviews and reflect on the extent to which they are in opposing camps on the concern about the ecological crisis. The New Ecological Paradigm Scale was applied to two previously published independent samples of Portuguese students (9th grade and higher education students') for which subscales for ecocentrism and anthropocentrism worldviews were selected through factor analysis. Our results show that more than 40% of those that agree with ecocentrism does not rejects anthropocentrism, being mostly neutral to that worldview and some even agreeing with it. As so, anthropocentrism may be helpful, until a certain point, to the changes needed to tackle present ecological crisis. In face of this, we propose further studies on the different anthropocentric facets to selected those that may be included in environmental education effort to help, together with ecocentrism, to fight back ecological crisis.

Keywords: New ecological paradigm, environmental attitude, ecocentrism, Anthropocentrism, environmental education

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INTRODUCTION

Since the 1970s, human resource consumption and pollution emissions have surpassed Earth's biocapacity, and a global ecological crisis has started to grow. Despite several warnings over the past decades, humanity has not been able to rebalance its activities within the limits of the planet, and its ecological footprint is growing rapidly and soon could be twice the Earth's biocapacity (Earth Overshoot Day, 2022). Consequently, several global imbalances currently affect the Planet, with climate change being at the forefront of this ecological crisis. Considered one of the worst threats that humanity ever faced, climate change is presently affecting humans and the global natural system, demanding for an urgent action in adaptation and mitigation considering its serious consequences (IPCC, 2023). Besides the need for efficient technologies and the control of human population growth, cultural change is crucial to overcome this ecological crisis (Plumwood, 2002). Drifting from present consumerism and anthropocentric cultures to most ecocentric and environmental cultures has been proposed to rebalance the relationship between human activities and the planet (Sessions, 1974; Black et al., 2017). To address these changes, hope has been put into environmental education efforts over the past decades. Environmental education has as its main goal to promote environmental literacy, a concept that includes, among others, environmental knowledges, attitudes, and behaviours (Hallfreðsdóttir, 2011; Krnel & Naglič, 2009; Igbokwe, 2012; McBeth & Volk, 2010; Kuhlemeier, et. al., 1999; Pe'er et. al., 2007). Promoting environmental attitudes among modern societies is crucial for the process of the cultural change needed to overcome the present ecological crisis (Gardner & Stern, 1996). Environmental attitude can be understood as a psychological tendency expressed by a favourable or unfavourable evaluation of the natural environment (Eagly & Chaiken, 1993; Milfont & Duckii, 2010). Although Yin (1999) considers it as people's orientation toward environmentally related objects structured in cognitive, affective, and evaluative dimensions, Albarracín et al. (2005) argue that the attitude concept should be reserved only for the evaluative dimension. Despite under debate, some authors have proposed a structure for environmental attitude with two main dimensions (Blaikie, 1992; Milbrath, 1984; Milfont & Duckitt, 2004). Wiseman and Bogner (2003) summarized this structure by identifying a dimension that captures the preservation of the environment (biocentric) and another that points to interest in nature utilization (anthropocentric). However, Wiseman and Bogner (2003) pointed out the inexistence of reasons to suppose that these two dimensions (ecocentric and anthropocentric) are always contrasting and may also be seen as complementary.

The New Ecological Paradigm (NEP) scale (Dunlap & Van Liere, 1978; Dunlap et al., 2000) has been used in the past decades to evaluate the prevalence of pro-environmental attitudes. First, the NEP scale (Dunlap & Van Liere, 1978) was a 12 items version instrument to evaluate the level of concern about environmental quality, but after a revision (Dunlop et al., 2000) it becomes a 15 items scale to measure two main worldviews: ecocentric (agreeing with a New Ecological Paradigm) and anthropocentric (agreeing with the Dominant Social Paradigm) (Kilbourne et al., 2002; Lundmark, 2007). After evaluating its dimensionality, Lopez-Bonilla and Lopez-Bonilla (2016) found that the NEP scale has two sides (ecocentrism and anthropocentrism) but criticized the maintenance of the two paradigms within the same scale.

Ecocentrism assumes that nature has value for itself and needs to be preserved, and anthropocentrism considers nature to be used and controlled by humans and for its own benefit.

The present study incorporates Lopez-Bonilla and Lopez-Bonilla (2016) considerations about the NEP scale and uses two different subscales (one for ecocentric worldview and another for anthropocentric) to assess Wiseman and Bogner (2003) conclusions, who stated that these two dimensions do not have to be incompatible. As such, the present study aims to assess to which extend ecocentrism and anthropocentrism are each other compatible. Considering Wiseman and Bogner (2003), our hypothesis is that ecocentrism is not incompatible with anthropocentrism.

METHOD

To determine whether an ecocentric worldview is incompatible with anthropocentrism, we followed a new approach using the New Ecological Paradigm (NEP) scale (Dunlap and Van Liere, 1978; Dunlap et al., 2000) and data samples from two previously published studies: one with 9^{th} grade students (459 samples) (Spínola, 2015) and another with higher education students (220 samples) (Spínola, 2023), both residents of Madeira Island (Portugal). Data were collected in April 2014 for the study Spínola (2023) and in May 2013 for Spínola (2015). The two data samples were chosen for reasons of convenience, firstly because the author has access to their base data, secondly because they refer to two different age groups and thirdly because they both originate from the same population. At the time data were collected, the University of Madeira had no Ethical Board, and the Spínola (2023) study approval was tacitly given by the rectorship when accepting to distribute the online and anonymous survey to all the students of the institution. The University of Madeira students who voluntarily accepted to participate in the study gave online informed consent. The Spínola (2015) study was conducted in five local schools and, in each one, the School Board had approved the anonymous questionnaire application to their 9th grade students, following their usual procedures of informing parents and obtaining their written consent.

Each of the two sample groups was analysed separately using the IBM SPSS Statistics software (version 27), under copyright license attributed to University of Madeira. Samples with missing data were excluded from the analysis, and for each of the NEP scale items, data were transformed into numeral scores (1-Strongly disagree, 2-Mildly disagree, 3-Unsure, 4-Mildly agree, and 5-Strongly agree). Factor analysis was performed to select the NEP items to be used in the construction of the ecocentrism and anthropocentrism scales. First, the Kaiser–Meyer–Olkin (KMO) measure (Kaiser, 1974) and Bartlett's Test of Sphericity (Bartlett, 1954) were used to test data adequacy for factor analysis. After confirming that the Kaiser-Meyer-Olkin measure of the sampling adequacy index was higher than 0.6, and the significance of Bartlett's test of sphericity, an Exploratory Factor Analysis (EFA) was conducted to define the NEP items to compose the ecocentric and anthropocentric subscales. First, EFA, using Principal Component Analysis with Varimax rotation and Kaiser normalization, was forced to extract only two components to fit our model. For each component extracted, items explaining more than 50% of the variance and showing negative or neutral factor loadings in the opposite component were selected to compose the ecocentric and anthropocentric subscales. Both the subscales and for each sample group were tested for appropriateness for factor analysis through the KMO measure and Bartlett's Test of Sphericity. After confirming its appropriateness, Confirmatory Factor Analysis (CFA) was conducted for both subscales.

After defining the NEP subscales for ecocentric and anthropocentric worldviews, both were evaluated for reliability (Cronbach's alpha) and validity (Pearson correlations). To test our hypothesis that ecocentrism is not incompatible with anthropocentrism, we calculated the mean score for ecocentric and anthropocentric worldviews and then the prevalence of each profile that results from the combination of both worldviews. For each worldview (ecocentric and anthropocentric), mean scores lower than 2.5 was considered to have disagreeing, between 2.5 and 3.4 as neutral, and higher than 3.4 as agreeing.

RESULTS

Sample Characterization

The 9th grade students' samples (n=459) from five elementary schools located in Madeira Island (Portugal) had a mean age of 15 years, with males (51.3%) being slightly more prevalent than females (48.7%). Higher education students (n=220) from the University of Madeira had a mean age of 25 years, ranging from 18 to 60 years, with a higher prevalence of females (70%). Most of them were undergraduate (73.6%) and master's (20.9%) students, but some were attending technical (2.7%), doctoral (1.8%), or other (0.9%) course levels. In this research, the ethics committee approval notification document containing the eligibility decision for the research was received from the Center for Research in Education of the University of Madeira Ethic Committee (ethics approval number 71/CEUMA/2023).

Appropriateness for Factor Analysis

Data from both samples, 9th grade students and higher education students, had a normal distribution and were appropriate for factor analysis since the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.75, and Bartlett's Test of Sphericity was significant ($p<0.001$). The first Exploratory Factor Analysis with data from 9th grade students selected nine NEP items that fit the model of two dimensions, five items for the ecocentric subscale, and four for the anthropocentric subscale. These nine NEP items were appropriate for factor analysis (KMO measure 0.80, and significance on Bartlett's Test of Sphericity, $p<0.001$).

Ecocentric and Anthropocentric Subscales

A Confirmatory Factor Analysis with these nine items extracted 45% of the total variance on two factors: one for ecocentric items (32% of variance) and another for anthropocentric items (13% of variance) (Table 1). For higher education students, 11 NEP items were selected to fit the two-dimensional model after an Exploratory Factor Analysis, six items constituting the ecocentric subscale and five the anthropocentric. These 11 NEP items were appropriate for factor analysis scoring 0.77 for the KMO measure, and significant for Bartlett's Test of Sphericity ($p<0.001$). A Confirmatory Factor Analysis with these 11 items extracted 44.6% of the total variance on two factors, one for ecocentric items (29.7% of variance) and another for anthropocentric items (14.9% of variance) (Table 2).

Table 1. Madeira Island 9th grade students. Factor loadings for NEP scale obtained from Principal Component Analysis with Varimax rotation after removing items that do not fit to the proposed model of a two-dimensional structure (ecocentric and anthropocentric).

NEP Items↓	**Factor loadings**		**Worldview classification**
	1	2	
Eigenvalues→	2.89	1.17	
Q3▪ When humans interfere with nature, it often produces disastrous consequences.	0.63	-0.29	Ecocentric
Q5▪ Humans are severely abusing the environment.	0.70	-0.16	Ecocentric
Q7▪ Plants and animals have as much right as humans to exist.	0.69	-0.01	Ecocentric
Q9▪ Despite our special abilities, humans are still subject to the laws of nature.	0.59	-0.16	Ecocentric
Q15▪ If things continue their present course, we will soon experience a major ecological catastrophe.	0.62	-0.08	Ecocentric
Q2▪ Humans have the right to modify the natural environment to suit their needs.	-0.15	0.64	Anthropocentric
Q4▪ Human ingenuity will ensure that we do not make the Earth unliveable.	-0.03	0.63	Anthropocentric
Q12▪ Humans were meant to rule over the rest of nature.	-0.34	0.60	Anthropocentric
Q14▪ Humans will eventually learn enough about how nature works to be able to control it.	-0.10	0.72	Anthropocentric
Variance accounted by each factor	32%	13%	

Table 2. Higher education students. Factor loadings for NEP scale obtained from Principal Component Analysis with Varimax rotation after removing items that do not fit to the proposed model of a two-dimensional structure (ecocentric and anthropocentric).

NEP Items↓	Factor loadings		Worldview classification
	1	2	
Eigenvalues→	3.26	1.64	
Q3▪ When humans interfere with nature, it often produces disastrous consequences.	0.66	-0.13	Ecocentric
Q5▪ Humans are severely abusing the environment.	0.78	-0.19	Ecocentric
Q7▪ Plants and animals have as much right as humans to exist.	0.59	0.03	Ecocentric
Q9▪ Despite our special abilities, humans are still subject to the laws of nature.	0.72	-0.12	Ecocentric
Q11▪ The Earth is like a spaceship with very limited room and resources.	0.58	-0.01	Ecocentric
Q15▪ If things continue their present course, we will soon experience a major ecological catastrophe.	0.69	-0.16	Ecocentric
Q2▪ Humans have the right to modify the natural environment to suit their needs.	0.06	0.60	Anthropocentric
Q4▪ Human ingenuity will ensure that we do not make the Earth unliveable.	0.001	0.64	Anthropocentric
Q8▪ The balance of nature is strong enough to cope with the impacts of modern industrial nations.	-0.21	0.54	Anthropocentric
Q12▪ Humans were meant to rule over the rest of nature.	-0.27	0.56	Anthropocentric
Q14▪ Humans will eventually learn enough about how nature works to be able to control it.	-0.09	0.75	Anthropocentric
Variance accounted by each factor	29.7%	14.9%	

The Cronbach's Alpha scores were 0.68 and 0.77 for the ecocentric subscales with 9th grade students and higher education students, respectively, and 0.59 and 0.63 for the anthropocentric subscales. These reliability scores were not high, particularly for the anthropocentric subscales, but they were acceptable because the number of items in each subscale was low (Taber, 2018). The validity of the subscales was confirmed for all items since they showed positive and significant ($p<0.01$) Pearson correlations.

Ecocentric and Anthropocentric worldviews

The concordance with the ecocentric worldview and disagreement with anthropocentrism was high in both samples, but significantly better for higher education students (Table 3). In contrast, disagreement with ecocentrism and agreement with anthropocentrism was residual for both groups, except for the anthropocentric view among 9th grade students that reached 12.2%. The neutral attitude was lower for ecocentrism than anthropocentrism in both groups, but significantly higher for both worldviews in 9th grade students. When evaluating the mean score in each subscale, it is also evident the clear support of an ecocentric view in both groups (Ecocentric subscale: 9th grade students 4.1 s.d.± 0.6; higher education students 4.3 s.d.± 0.6) but a lower level of rejection for the anthropocentrism among 9th grade students (Anthropocentric subscale: 9th grade students 2.5 s.d.± 0.72; higher education students 2.1 s.d.± 0.58).

Table 3. Ecocentric and Anthropocentric concordance levels for 9th grade and higher education students.

Worldview	Concordance (score)	9th grade students (n=459)	Higher education students (n=220)
Ecocentric	Agree (>3.4)	86.4%	92.6%
	Disagree (<2.5)	1%	1.9%
	Neutral (2.5-3.4)	12.6%	5.5%
Anthropocentric	Agree (>3.4)	12.2%	1.9%
	Disagree (<2.5)	41.8%	72.7%
	Neutral (2.5-3.4)	46%	25.4%

Significant results between both groups are bold marked ($p<0.05$).

Table 4 shows the prevalence of the Ecocentric/Anthropocentric profiles and reveals that Agree/Disagree was the most prevalent for both sample groups but was significantly higher for higher education students. In concordance with the results shown in Table 3, the Agree/Neutral profile was the second most prevalent and significantly higher for 9th grade students.

Table 4. Ecocentric and Anthropocentric mean scores profile prevalence for 9th grade and higher education students.

Ecocentric/Anthropocentric Profiles	9th grade students n=459	Higher education students n=220
Agree/Agree (AA)	**9.4%**	**1.8%**
Agree/Disagree (AD)	**40.5%**	**70%**
Agree/Neutral (AN)	**36.4%**	**20.9%**
Disagree/Agree (DA)	0.2%	0%
Disagree/Disagree (DD)	0%	1.8%
Disagree/Neutral (DN)	0.9%	0%
Neutral/Agree (NA)	2.2%	0%
Neutral/Disagree (ND)	1.1%	0.9%
Neutral/Neutral (NN)	**9.4%**	**4.5%**

Significant results between both groups are bold marked ($p<0.05$).

Considering the purpose of the present study, to clarify if agreeing with an ecocentric worldview implies rejecting anthropocentrism, we need to take into consideration the prevalence of the following profiles, which agree with ecocentrism and do not reject anthropocentrism: Agree/Agree and Agree/Neutral. From Table 4, we can see that these two profiles together have a prevalence of 45.8% and 22.7% in 9th grade and higher education students, respectively. Of the 396 students (86.4%) from the 9th grade that agreed with ecocentrism, 53% did not reject anthropocentrism, being neutral (42%), or agreeing with it (11%). Among the 204 higher education students (92.7%) who agreed with ecocentrism, 24.5% did not reject anthropocentrism, most of them being neutral (22.5%). In addition, considering both sample groups together, among the 600 students who agreed to an ecocentric worldview, 43.3% (260 students) did not reject anthropocentrism. Our data strongly suggest that it is possible to be ecocentric without rejecting anthropocentrism, and even agree with it.

DISCUSSION

Much of the literature that discusses the underlying causes of the present ecological crisis assumes the anthropocentric worldview to be the main responsible (Dunlap 2008; Shoreman-Ouimet and Kopnina 2016; Stern and Dietz 1994; Stern 2000;). In this view, intensive resource exploitation and mass pollution emissions are undertaken because humans see themselves as being high above nature and feel legitimated to manage it to fulfil their needs and desires. To tackle the ecological crisis and rebalance human activities within the limits of the planet, a shift in human vision has been proposed: abandoning anthropocentrism and embracing an ecocentric worldview (Kortenkamp and Moore 2001; Kopnina 2015; Thompson and Barton 1994). In contrast, some authors argue that humans' self-interest in maintaining a natural balance for their own sake gives the same result as an effort done because of natural intrinsic values (Hayward, 1997; Norton, 1984; Weston, 1985). This means that, at the end of the day, anthropocentrism will demand nature protection, since humans depend on it.

Present study shows clearly, as stated by Wiseman and Bogner (2003), that supporting an ecocentric worldview doesn't mean necessarily an anthropocentrism rejection (Table 4). In fact, considering both sample groups, more than 43% of ecocentrism supporters do not reject anthropocentrism, being mostly neutral to that worldview, and with a minority agreeing with it. Despite the controversy regarding the compatibility between ecocentrism and anthropocentrism (Kopnina et al., 2018), our results show a scenario in which a high prevalence of the ecocentric worldview is intermingled with, as Norton (1984) calls it, 'week anthropocentrism'. Although the majority of ecocentrist supporters reject anthropocentrism (56.7%), our results ask for a reformulation of this dualistic vision to better discriminate between those attitudes that support environmental protection from those that oppose it.

First, we need to consider that our results could have been influenced by the research instrument that we chose to use, the NEP scale (Dunlap et al., 2000), which means we need to validate them with a future study using an alternative scale that can discriminate between ecocentric and anthropocentric worldviews. For this purpose, the Ecocentric and Anthropocentric Attitudes Toward the Environment (EAATE) scale (Thompson and Barton, 1994) could be used. Meanwhile, after analysing the items selected from the NEP scale to set up the anthropocentric subscale, it seems to us that none can discriminate between an anthropocentrism that rejects the care for nature and another that supports sake of humans. As such, the overlap between ecocentrism and anthropocentrism that we found in our results could be the effect of a belief in humans' ability to ensure that we will not 'make the Earth unliveable' (Q4) and that we will be able to fully understand nature and control our negative impacts (Q14). In fact, less than half of the respondents rejected these two anthropocentric statements, in contrast to the other statements that only considered the acceptance of human pressure and dominance over nature (Q2, Q8, and Q12), to which high levels of rejection were found (about two-thirds) (data not shown). We believe that this partial compatibility between an ecocentric worldview and anthropocentrism could correspond to an anthropocentric facet that supports the belief that humans can overcome the present ecological crisis. In fact, this profile was also found in previous studies (Atav, et al., 2015; Castro and Lima, 2001; Denis and Pereira, 2014; Ntanos, et al., 2019; Spínola, 2015; Vidal et al., 2022) and it can mean faith in the human ability to rebalance himself with the limits of the planet. As such, it may be seen as a constructive hope that could help to engage in positive environmental behaviors (Ojala, 2012 and 2017), and, as such, could be perfectly compatible with an ecocentric worldview.

Thus, the need to study the anthropocentric worldview better becomes evident, discriminating between the one whose utilitarian interest in nature leads to its destruction from the one that requires and promotes its preservation. Future studies with adequate research instruments should clarify which facets of anthropocentrism may be promoted through environmental education, alongside an ecocentric worldview, to help fight present ecological crisis.

DECLARATIONS

Ethical Considerations: In this research, the ethics committee approval notification document containing the eligibility decision for the research was received from the Center for Research in Education of the University of Madeira Ethic Committee (ethics approval number 71/CEUMA/2023).

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Beyond the Acronym: Entwining STEAM Education, Self-Regulation, and Mindfulness

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ABSTRACT

Research Article

This study examines the philosophical constructs of Science, Technology, Engineering, Art, and Mathematics (STEAM) curricula entwined with self-regulation and mindfulness to afford students holistic learning. STEAM education is often presented as STEM, resulting in the loss of blended arts integration. The researchers present rationale for including the arts to provide students with interdisciplinary and transdisciplinary curricula that promotes increased creativity and emotive connections to learning. Blending of the arts in STEAM provides students with a greater depth and breadth of critical-thinking, creative-thinking, and social-emotional connections to content. The social capital and emotive connections students construct in STEAM learning present educators with opportunities to entwine mindfulness practices to empower students to develop confidence and competence in their STEAM abilities. Entwining STEAM, self-regulation, and mindfulness provides both a canvas and laboratory of aesthetic, holistic learning of the mind and spirit. The researchers provide instructional and clinical professional practices as well as recommendations for STEAM as a construct for not only providing opportunities for students to engage in cognitive progression, but also to assist learners in developing social, emotional, and behavioral skills for lifelong regulatory and mindfulness learning.

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INTRODUCTION

The entwining of disciplines provides opportunities for teachers and students to engage in relational-rich education that affords multiple perspectives for learning. Entwined Science, Technology, Engineering, and Mathematics (STEM) and the inclusion of Art for STEAM are philosophical constructs that include entwining content to allow students to investigate phenomena and engage in constructivist, discovery-based learning. Both STEM and STEAM prioritize teaching and learning through the amalgamation of interdisciplinary and transdisciplinary teaching and learning to support the cognitive, social, emotional, and behavioral needs of all learners. While this paper emphasizes STEAM education, both STEM and STEAM are catalysts for entwining interdisciplinary and transdisciplinary learning within the acronym and beyond the acronym for holistic learning. Employing a STEAM philosophical approach to teaching and learning creates authentic learning opportunities that involve connecting prior knowledge with new experiences and skills in a natural environment, thus fostering meaningful learning (Jia et al., 2021). Entwining art within and beyond the acronym results in interdisciplinary and transdisciplinary real-world holistic learning that allows for creative expression, fosters critical thinking, and provides a means of communication and understanding across cultures (Henriksen, 2017). The inclusion of the arts creates multiple pathways for students to engage in collaborative learning through creativity and inquiry for academic development as well as mindful, emotive learning.

Philosophy of Mindfulness

The philosophy of mindfulness is rooted in various contemplative traditions, particularly within Buddhism, and has gained significant attention within the field of psychology. Mindfulness can be conceptualized as a state of open and non-judgmental attention to the present moment, characterized by an awareness of one's thoughts, emotions, and sensory experiences (Kabat-Zinn, 1990). The philosophy of mindfulness is based on the idea that individuals can gain deeper insight into their own minds and behavior through intentional and non-judgmental awareness. Mindfulness practice often involves cultivating attention and present-moment awareness through various techniques, such as meditation, breathing exercises, and body scanning (Bishop et al., 2004). Through sustained practice, individuals can develop a greater ability to observe their thoughts and regulate emotions.

Entwined Cognitive and Emotive Learning

Interdisciplinary, transdisciplinary STEAM learning fosters the development of a social environment that impacts student creativity and self-efficacy by promoting a prosocial atmosphere that supports students in experimenting and exploring capabilities (Conradty & Bogner, 2020). STEAM learning influences students' emotions due to the interdisciplinary, transdisciplinary, and solution-oriented characteristics of STEAM course content (Li et al., 2022). Entwining STEAM and mindfulness provides a canvas and laboratory of aesthetic, holistic learning of the mind and the spirit. STEAM is a construct that not only provides opportunities for cognitive progression, but also assists in the development of social-emotional skills for regulatory learning. Much like mindfulness, STEAM affords learners opportunities to engage in the construction of knowledge as well as the development of social awareness, interpersonal interactions, and prosocial skills through collaboration and personalized learning. Constructivist-based STEAM education creates an environment for students to participate in real-life situations and cultivate empathy through practical experiential learning (Lam et al., 2019). Cognitive, social, emotional, behavioral, and mindful learning provides students in STEAM education settings with skills to achieve lifelong academic goals and collaborate with others.

STEAM Classroom Settings

Collaboration

Authenticity in STEAM is significant as it ensures students engage in real-world, relevant problems at the intersection of arts and STEM, fostering practical learning experiences (Dell'Erba, 2019). STEAM benefits the social skills development of children as early as primary school by enhancing self-image, self-esteem, self-efficacy, resilience, tolerance, empathy, teamwork skills, and assertive communication abilities (Voicu et al., 2022). When learners possess emotional awareness, they are better positioned to work with others and enabled to employ insight for problem-solving. Peer interactions impact bonding-cognitive/affective social capital by providing support, acceptance, and informational resources within STEM education (Saw, 2020). Engaging in collaborative team learning is essential for both STEM and STEAM, and when students are emotionally aware, they can engage in emotionally regulated inquiry, critical thinking, and problem-solving. STEAM fosters student autonomy, curiosity, and inquiry through project-based and student-centered learning and provides a foundation for prosocial collaboration, emotional regulation, and active engagement (Weyer & Dell'Erba, 2022).

Social Capital

STEAM cultivates confidence by allowing students to participate in cross-disciplinary, practical learning activities that enable students to utilize abilities across multiple disciplines, thereby nurturing a feeling of proficiency and self-assurance (Rikoon et al., 2018). STEAM affords new ways to engage emotions, impacting both cognitive and emotional aspects of teaching and learning. Emotional regulation is foundational for cognitive learning and influences how learners approach education. Emotions are vital in education, as they significantly influence the learning process by affecting memory, attention, and cognitive abilities (Steele & Ashworth, 2018). Emotions, motivation, and social recognition are important factors that influence students' STEAM academic achievement and social-emotional learning (Li et al., 2022). Emotional awareness is a precursor of emotional regulation, which influences social interactions for building capital. As a result of these entwined learning pathways, the construction of social capital enables students to access resources, supports, and networks through social connections, which is beneficial for academic achievement and possible career paths in STEM (Saw, 2020).

Personalized Learning

In a study conducted by Voicu et al. (2022), STEAM education during primary school provided children with vital skills and attributes that are essential for their personal growth, academic progress, and future achievements in diverse areas of life. As learners build capital, they are motivated to engage in further collaborative, interactive learning experiences with peers, thereby continuing the cycle of building capital and personalizing the learning. The personalization of learning facilitates improved academic outcomes as well as an increased ability to regulate emotions for meaningful sensory experiences. STEAM provides opportunities for collaborative and personalized learning and has a positive effect on students' social capital by nurturing creativity, recognizing diverse learning styles, increasing student engagement, and potentially enhancing STEM learning through shared skills in STEM, arts, and design (Allina, 2018).

Creativity of Expression

Transdisciplinary learning impacts students by enabling them to combine knowledge and skills from multiple disciplines, nurturing a comprehensive conceptualization of intricate real-world issues, and encouraging creativity, critical thinking, and innovation (Rikoon et al., 2018). Understanding and addressing emotions is crucial for successful teaching and learning, and the multidisciplinary and transdisciplinary nature of STEAM engages and capitalizes on student emotions (Steele & Ashworth, 2018). When students think critically and innovatively, they engage in discovery learning for creativity in problem-solving through experiential, sensory learning. Sensate experiences in a prosocial learning environment create an atmosphere for actuated learning. STEAM learning environments foster motivation by promoting students' autonomy and creativity on an ongoing basis (Conradty & Bogner, 2020).

Conceptualizing STEAM and Mindfulness

Gears, Degrees, and Ratios of Entwinement

In blended interdisciplinary and transdisciplinary STEAM learning environments, science, technology, engineering, art, and mathematics work in unison for entwined cognitive, social, emotional, and behavioral development. Transdisciplinary STEAM fosters creative and critical thinking as a result of blending the arts within STEM (Wilson et al., 2021). However, each discipline is not required and should not be expected to be equally emphasized within each lesson or unit of study. The researchers emphasize an analogy of this degree of synchronous relation to the gears of a mechanical device, moving in synchrony and transmitting torque from one gear to the next, but with different proportions. Much like the meshing of gears for synchrony, as educators, the researchers highlight that we must recognize that the intricate movements within the acronym of STEAM may differ in analogous gear size, degrees, and ratios. Through blended learning, there may be, on occasion, a greater emphasis on the gears of technology, engineering, and mathematics, resulting in greater "turns" and ratios than the other gears of science and art. Entwined learning allows for changes in breadth and depth from one

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discipline to the next, yet unified for blended, interdisciplinary and transdisciplinary learning (Figure 1).

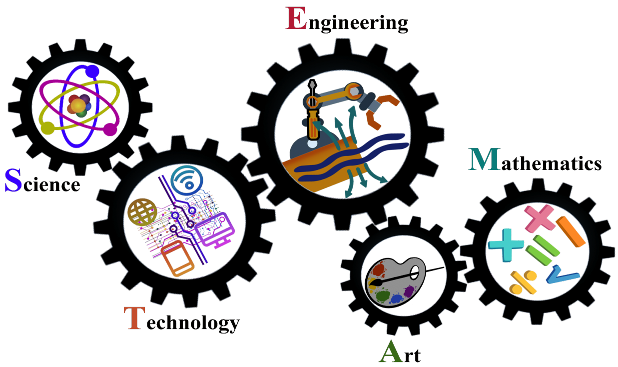

Figure 1. Gears of STEAM learning

The intricate movement of gears within a mindfulness construct are the meshing of gears for establishing open and non-judgmental emotive and cognitive awareness for empathy and social skills. In addition, each conceptual mindfulness turn also creates attention to the present moment and provides an equal awareness of sensate experiences for self-management, self-regulation, and self-actualization. The researchers' conceptualization of the degrees of mindfulness learning results in synchronous relational pathways for both social skills development and self-actualization. Mindfulness transmits torque for learners to observe and gain insight into their thoughts, which results in the development of empathy and social skills and the regulation of emotions for actualization (Bishop et al., 2004; Kabat-Zinn, 1990). Similar to how the synchronization and interlocking of gears ensure smooth and efficient mechanical operation, mindfulness techniques empower learners to cultivate an acute awareness of their thoughts. Student enhanced observations aid in regulating emotions, fostering empathetic social skills development, and balanced regulation for actualization (Figure 2).

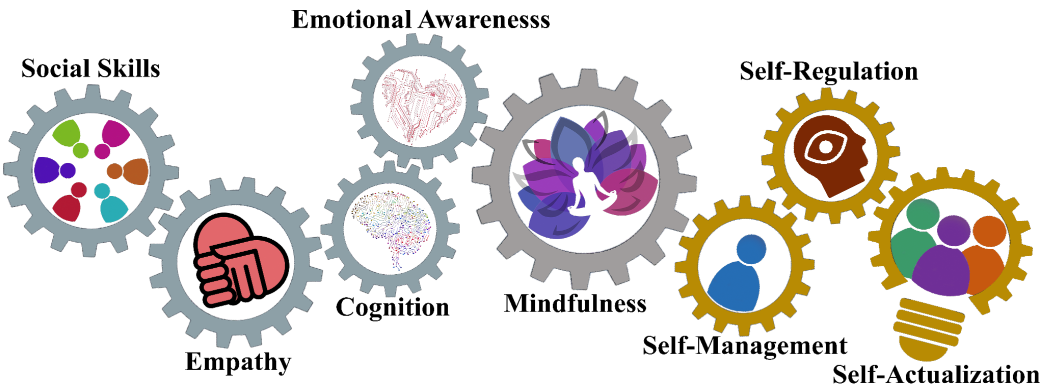

Figure 2. Gears of mindfulness learning

In addition, learning is complex. The STEAM and mindfulness gears of synchrony influence one another, with each movement causing countermovements from clockwise to counterclockwise. As such, STEAM and mindfulness learning environments are intricate and interactive because they are entwined spaces for independent, personalized learning as well as socialized learning, self-management, and self-regulation for self-actualization. STEAM education combined with critical thinking positively impacts students' social development by fostering empathy, reflective thinking, enhancing problem-solving abilities, and promoting collaborative efforts for social-emotional growth (Lam et al., 2019; Mariana & Kristanto, 2023). Philosophically, STEAM learning environments are places for degrees of movement, establishing the conditions for an atmosphere that facilitates self-regulation and mindfulness in learning. Integrating STEAM education with critical thinking enhances students' self-regulation by encouraging them to set goals that promote perseverance (Lam et al., 2019) (Figure 3).

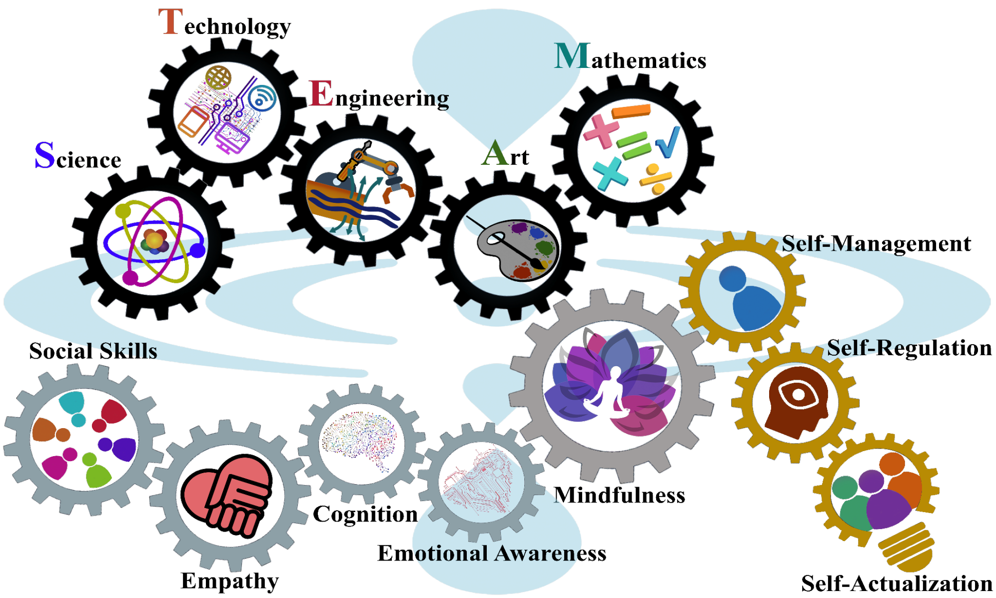

Figure 3. Gears of synchrony for STEAM, mindfulness, and self-regulation

Historical Context: STEAM Education

Interdisciplinary and Transdisciplinary Learning

Interdisciplinary approaches involve collaboration between different disciplines to address a specific issue, while transdisciplinary approaches entwine knowledge and methods from multiple disciplines in a way that transcends traditional academic boundaries, focusing on holistic problem-solving and the application of integrated knowledge to real-world challenges (Liao, 2016). Promoting the development of a holistic mindset in learners is vital for developing the whole child, which includes cognitive and social domains for mindset and emotive actualization. By breaking down traditional disciplinary boundaries, transdisciplinary education promotes a holistic understanding of issues and fosters innovative solutions with a meaningful impact on society and the environment (Clark & Button, 2011). Creating opportunities for students to utilize critical thinking skills within an emotionally supportive environment enables learners to cognitively and emotionally explore solutions with an asset-mindset for creative problem-solving. Transdisciplinary STEAM learning facilitates students exploring and solving problems using multiple perspectives, leading to more innovative and effective solutions (Amalu et al., 2023).

From STEM to STEAM

Interdisciplinary and transdisciplinary teaching and learning are central tenets of STEM and STEAM education. However, STEM and STEAM are relatively new teaching and learning philosophical approaches for cognitive and emotive blended learning. In response to 21st-century challenges and in an effort to blend disparate content, the acronym SMET (Science, Mathematics, Engineering, and Technology) was conceived by the United States National Science Foundation (NSF) in the 1990s, which was later reframed as STEM by the NSF's Education and Human Resources Directorate (Breiner et al., 2012; Widya, et al., 2019). However, STEM philosophy did not simply begin with the NSF as a means to blend content. The initial concept of STEM education is primarily attributed to the launch of the Russian satellite Sputnik in 1957; this sparked a heightened emphasis on science and engineering education in the United States and marked the inception of STEM education (Granovskiy, 2018; Mohr-Schroeder et al., 2015). As STEM continued to be developed and refined, STEAM education was introduced in South Korea in 2011 as a strategy to reform STEM education by integrating "Art" into STEM (Widya, et al., 2019). Entwining art within the acronym STEM affords creativity throughout the interdisciplinary and transdisciplinary blended construct of STEAM. Intersections of cognitive and emotive learning occur throughout the acronym and influence learners' self-regulation for mindfulness. Integrating art into STEM education benefits students by enhancing convergent thinking, creativity, and character development and by providing a broader range of problem-solving approaches, ultimately preparing them for successful careers in growing fields such as sustainable energy technologies (Amalu et al., 2023).

Entwined Science of Learning

Incarnation of Constructivism

Constructivism is an essential theoretical methodology for facilitating STEAM education, as it empowers students to build knowledge through design processes and prepares students for the creative demands of 21st-century workplaces (Gross & Gross, 2016). STEAM teachers entwine constructivism within STEAM to design lessons and activities students engage in that provide opportunities to interact with peers, work independently, and employ discovery for creatively building knowledge. Constructivism supports students' cognitive, emotional, and social skills development through peer interactions and facilitates independent learning, inquiry, and connecting concepts in building knowledge (Zhu & Atompag, 2023). Inquiry allows students to examine phenomena and consider solutions for STEAM learning through hands-on experiential engagement. As a result, constructivism supports students' emotional regulation by prioritizing active participation in learning, enabling students to build their own comprehension, and offering hands-on experiences for autonomy, leading to emotional regulation (Videla et al., 2021). STEAM academic achievement, emotional regulation, and social constructivism are entwined processes that empower holistic learning. In research conducted by Kussmaul & Pirmann (2021), social constructivism was identified as a significant form of STEAM academic and social-emotional learning due to its focus on collaborative learning and social interaction, contributing to improved critical thinking and deeper comprehension of concepts. The process of students building knowledge through social interactions and problem-solving was a significant, influencing factor in cognitive and social-emotional learning. Entwined social interactions through collaboration support students as they socially regulate their emotions for self-actualization and develop a growth mindset.

Manifestation of Collaborating

The shift from STEM to STEAM learning provides several cognitive, social, emotional, and behavioral regulatory advantages for students. Entwining the arts in education links STEAM and emotional intelligence, fostering creativity and emotional awareness among students for meaningful collaborative learning (de Vries, 2021). In addition, entwining the arts creates opportunities for collaborative student engagement that fosters creative and critical thinking among learners. In research on STEAM education, Li et al. (2022) linked interdisciplinary and transdisciplinary STEAM environments with cultivating self-awareness of thoughts and developing problem-solving skills in students, which are fundamental for self-regulated learning. STEAM education fosters a growth mindset and enhances character-building skills in students by affording opportunities to learn through resilience, inquisitiveness, creativity, and problem-solving (Bertrand & Namukasa, 2020). Collaborating while engaging in interdisciplinary and transdisciplinary learning provides multiple opportunities for students to form relationships with peers and develop emotional awareness. STEAM learning affords a learning environment that supports the development of relationships and shared norms, which are important for cooperation and teamwork (Li et al., 2022). Affording students an environment to engage in academic learning while also developing social skills through collaboration and teamwork provides opportunities for learners to develop emotional awareness, self-regulation, and mindset. In research conducted by Kim et al. (2019), the investigators found that student academic success and emotional regulation resulted from the entwined, collaborative nature of STEAM learning and prolonged artistic collaborations. STEAM education enhances students' capacity to engage in collaborative research and problem-solving, which are crucial competencies for self-regulated learning (Li et al., 2022).

Externalization of Communicating

Collaborative, prosocial learning environments create conditions for students to engage in both academic and emotive experiential learning for constructive, effectual communications. STEAM promotes positive relationships and the sharing of multiple ideas, and it encourages the use of socially appropriate interactions, which are essential for effective communications (Belbase et al., 2022). The collaborative sharing of ideas provides opportunities for students to not only communicate their thoughts, but also question the thoughts of others in a non-confrontational manner for constructing shared knowledge. Collaborating creates a communicative effect for stirring students' natural curiosities and contributing to students' emotional development. Perales & Aróstegui (2021) emphasize the importance of the "emotional touch" in STEAM education due to its role in providing intrinsic motivation, enhancing communication skills, and contributing to the holistic development of individuals, aligning with the requirements of present and future society. STEAM education provides an environment for motivating learners and encouraging students to regulate emotions, which are key aspects of social-emotional learning for effective communications (Hsiao & Su, 2021). Student self-regulation contributes to a supportive, communicative environment for employing mindfulness and overcoming developmental obstacles. Mindfulness holds significance in STEAM learning environments as it shapes students' perspectives on challenges, their ability to persevere through obstacles, and their openness to embracing interdisciplinary methods through collaboration and communications (MacDonald et al., 2020).

Personification of Critical-Thinking

Constructivist learning environments empower students to take control of the learning by moving from a didactic lecture methodological approach for instructional delivery to a student-centered and student-led model for self-discovery and promotion of critical thinking. STEAM integrates creative and critical thinking by offering learning opportunities that capture students' interest, present challenges, and enable them to collaboratively design solutions (Henriksen, 2017; Mariana & Kristanto, 2023). STEAM learning environments that embrace self-regulated mindfulness allow students to engage in problem-solving through analyzing and evaluating data and information. In these types of learning environments, students are afforded a welcoming space to question and assess learning through critical thinking. In STEAM learning environments, critical thinking empowers students to analyze and generate solutions in tandem with creative thinking, which fosters the expression of original ideas (Mariana & Kristanto, 2023; Wilson et al., 2021). STEAM education and critical thinking positively influence students' social-emotional learning by nurturing empathy, problem-solving skills, and collaboration for social-emotional development, which fosters the utilization of goal setting for perseverance (Lam et al., 2019).

Actualization of Creative-Thinking

Entwining art throughout STEM education motivates student learning and affords opportunities for creative expression (Perignat & Katz-Buonincontro, 2019). A STEM to STEAM education provides a learning environment for students to engage in constructivist problem-solving and an atmosphere of collaboration, prosocial communications, critical thinking, and creative thinking. A learning environment that supports the cognitive needs of students in addition to the social, emotional, and behavioral needs for emotional awareness creates conditions for mindfulness. By entwining art throughout STEM, STEAM fosters a more comprehensive understanding of the subject matter, resulting in perspective-taking, emotional connections, and creativity (Leavy et al., 2023). In addition, STEAM learning provides a social environment that influences student creativity and self-efficacy (Conradty & Bogner, 2020). Utilizing creative forms of expression to showcase comprehension not only improves students' grasp and recall of the material but also fosters independence and self-assurance as students delve into and articulate their ideas. STEM educators can contribute to the development of mindfulness in

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students by offering chances for students to creatively explore and articulate their ideas (Larkin 2015). Constructing knowledge includes collaborating and communicating to facilitate critical thinking and creative thinking. Dignam (2021) posits STEAM education consists of five cyclic processes; Constructivism, the interchangeability of Collaboration and Communication, and finally, the exchangeability of Critical-Thinking and Creative-Thinking (Figure 4).

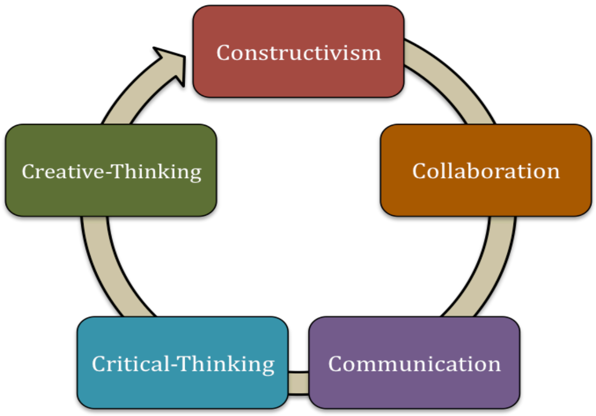

Figure 4. Dignam's 5 Cs of STEAM education

Historical Context: Mindfulness

A Universal Perspective

While originating from Eastern tradition, Western culture has witnessed a rise in the adoption of mindfulness techniques. Jon Kabat-Zinn, an American professor, is widely recognized in Western society for his contributions to the field of mindfulness. Specifically, he is known for his pioneering work in developing mindfulness-based stress reduction (MBSR) in the 1970s (Zenner et al., 2014). Kabat-Zinn defines mindfulness as the state of being aware and fully present in the current moment, achieved via the deliberate act of attentively observing one's experiences with an open and receptive mindset (Kabat-Zinn, 1990). Bishop et al. (2004) proposed a bipartite framework for delineating mindfulness. The initial component of self-regulation is the ability to concentrate on one's current experience, leading to heightened awareness of mental events occurring in the present moment (Bishop et al., 2004). The second phase involves cultivating a specific mindset towards one's current experiences, characterized by "curiosity, openness, and acceptance" (Bishop et al., 2004, p. 232). Mindfulness-based activities are now widely used in cognitive and behavioral mental health programs and school-based curricula.

A School-Based Perspective

The emergence of mindfulness interventions in schools can be attributed to Kabat-Zinn's mindfulness-based stress reduction (MBSR) program. Kabat-Zinn initially developed MBSR to assist adults in coping with persistent pain and stress (Zenner et al., 2014). However, in the

1990s, he modified the program to be applicable to children and teenagers, resulting in a specialized version called mindfulness-based stress reduction for teens (MBSR-T). This program marked the first instance of a mindfulness program specifically tailored for educational settings (Zenner et al., 2014). Following the creation of MBSR-T, several mindfulness programs have been designed to educate students on self-regulation within school environments (Zenner et al., 2014). The influence of mindfulness-based interventions in schools has been notably substantial. Furthermore, mindfulness-based interventions (MBIs) have demonstrated the ability to enhance a student's self-regulation, self-compassion, attention capacity, and temporal window size (Zenner et al., 2014).

Mindfulness programs utilize various meditation techniques and strategies in their teaching and training approaches (Bishop et al., 2004; Tang et al., 2020; Zenner et al., 2014). Mindfulness approaches facilitate the cultivation of psychological well-being and enable students to gain the psychological capacities required for self-awareness, self-control, social awareness, interpersonal interactions, and prosocial skills (Berti & Cigala, 2020). Entwined mindfulness and STEAM philosophy pave pathways for students to engage in cognitive and emotive experiential learning for attention, working memory, critical thinking, creative thinking, problem-solving, self-regulation, and building social capital.

According to the Collaborative for Academic, Social, and Emotional Learning (CASEL, 2023), students must possess a number of these fundamental skills in order to achieve goals, cultivate positive peer relationships, develop a positive sense of self, make ethical choices, and thrive in the learning environment. The ability of students to utilize a positive sense of self facilitates prosocial interactions among learners in cooperative learning settings for engaging in STEAM-centered critical thinking and problem-solving (de Vries, 2021; Mariana & Kristanto, 2023). These interactions are critical for students and influence the construction of social capital. Providing students with an entwined, interactive, and supportive STEAM learning environment that promotes both cognitive and emotional learning affords learners multiple perspectives and pathways for developing an awareness of emotions and an increased ability to regulate emotions.

A Neuro-STEAM Perspective

Students' teenage years are a crucial time for mental health, as most mental health conditions tend to emerge during this period (Tudor et al., 2022). Given the high prevalence and complexity of mental health issues among adolescents, it is crucial to gain a better understanding of learners' mental health and the neuroscience of regulation. Studies have shown that school-based mindfulness can be effective in enhancing the mental health and self-regulation skills of young learners (Tudor et al., 2022). Neuroscience research has shown a growing interest in mindfulness meditation over the past two decades, with studies providing compelling evidence of how such practices can lead to structural and functional changes in the brain (Fox et al., 2014; Tang et al., 2020; Tang et al., 2015; Taren et al., 2015). Behavioral studies have indicated that mindfulness meditation can potentially benefit various cognitive domains, including attention, memory, executive function, and cognitive flexibility. These effects have been observed in multiple brain regions, such as the cerebral cortex, subcortical gray and white matter, brainstem, and cerebellum, which aligns with the diverse mental functions involved in mindfulness practices.

Mindfulness has the potential to promote positive social behaviors in learners by helping them become more attuned to their emotions, thereby improving their interactions with peers and bolstering their self-regulation (Berti & Cigala, 2020). It has been suggested that these changes occur by modifying brain connectivity patterns linked to general cognitive functions such as attention, self-reflection, rumination, and interoception. This shift may contribute to a restructuring of the self-schema, characterized by reduced inflexibility and a decrease in psychological symptoms (Crane et al., 2016). These neuroscientific insights into mindfulness pose significant implications for students dealing with emotional challenges. Mindfulness training, with its inherent emphasis on present-moment awareness, acceptance, and compassion, may offer these students a valuable tool for self-regulation and emotional management (Mitsea et al., 2023; Valero et al., 2022; Yuan, 2021).

STEAM nurtures active learning and social-emotional development (Weyer & Dell'Erba, 2022). Developing social-emotional skills through STEAM experiential learning provides students with abilities they can apply for self-regulating stress and focusing attention for executive functioning and attaining academic goals. STEAM increases self-assurance through hands-on, interdisciplinary learning experiences that enable students to apply their skills across various fields, fostering a sense of competence and confidence (Rikoon et al., 2018). In addition, STEAM promotes positive social interactions for modified neurological regulation and provides new ways to engage emotions by recognizing and dealing with the emotional side of learning (Steele & Ashworth, 2018). Just as mindfulness helps learners become more attuned to their emotions for prosocial behaviors, STEAM learning environments promote socialization for building social capital and enhancing self-regulation skills development. During the process of STEAM learning, positive emotions and active participation foster social connections and trust, which facilitates students working together on identifying solutions through interdisciplinary and transdisciplinary projects (Li et al., 2022).

Entwined Art of Learning

Realization of Self-Regulation

Self-regulation refers to an individual's ability to exercise control over their own responses and manage their attention, thoughts, emotions, and behaviors in the presence of distractions and impulses (Cary et al., 2023; Thomson & Jaque, 2017). Self-regulation involves finding strategies to deal with intense emotions, improving focus and attention, and effectively controlling behaviors to achieve goals and maintain positive social interactions (Montroy et al., 2016; Wang et al., 2022). Self-regulation can also be conceptualized as the capacity to adjust one's behavior in order to attain a goal despite potential distractions (Ezmeci & Akman, 2023; Izhar et al., 2022). This capacity is complex and combines higher-order and lower-level skills (Kopp, 1982; Williams et al., 2023). In an educational setting, the development of self-regulation is crucial. Without this skill, students may struggle to focus on tasks and engage meaningfully with others in the learning environment. STEAM education significantly improves students' self-regulation and emotional awareness by fostering creative collaboration and promoting interdisciplinary learning experiences that motivate learners to engage and persist in their efforts (Kim et al., 2019). Students with strong self-regulatory skills demonstrate intrinsic motivation, independence, and initiative in pursuing their educational goals, actively guiding their own learning process (Oates, 2019). Acquiring self-regulation skills empowers learners to actively participate in the learning process, and the cultivation of self-regulation directly enhances their readiness for learning (Brenner, 2022; Gu & Zhu, 2023; Long et al., 2021; Louick & Muenks, 2022; Zeilhofer, 2023).

Incorporation of Executive Functioning

Self-regulation is just one aspect of a broader set of skills known as executive functioning. Executive functioning encompasses a range of cognitive processes and abilities, including working memory, cognitive flexibility, inhibitory control, decision-making, and problem-solving (Dong et al., 2023; Gu & Zhu, 2023). Entwined STEAM learning enables students to participate in activities that encourage empathy, teamwork, and self-regulation, which contributes to the actualization of student emotional intelligence (de Vries, 2021; Li et al., 2022). These skills collectively contribute to students' ability to organize thoughts, plan and prioritize tasks, solve problems, make sound decisions, and regulate their behavior. Executive functioning skills contribute to students' academic achievement, personal development, and overall well-being for lifelong learning. Executive functioning encompasses a range of cognitive processes that facilitate the execution of conscious, goal-directed behaviors (Sawyer et al., 2021). In contrast, self-regulation is a broad concept that encompasses a range of self-initiated behaviors aimed at regulating thoughts, emotions, and actions (Blair & Raver, 2014; McClelland & Cameron, 2011). While the terms executive functioning and self-regulation are sometimes used interchangeably and exhibit overlapping definitions, their usage can vary across different scientific domains. However, it is generally accepted that these terms refer to similar cognitive processes involved in regulating thoughts, emotions, and behaviors (Blair & Raver, 2014; Meuwissen & Carlson, 2015).

Reification of Entwinement

Self-regulation and executive functioning are entwined constructs, and their integration is crucial for promoting student success in various aspects of life, including academic achievement, social interactions, and overall well-being. Through self-regulated STEAM education, students gain the ability to manage their own learning, identify objectives, assess progress, and interact with one another (Li et al., 2022). Self-regulation involves the ability to direct and sustain attention on a specific task or goal, while executive functioning supports cognitive processes, such as working memory and inhibitory control, that are central to attentional control (Follmer & Sperling, 2016). Moreover, self-regulation and executive functioning play crucial roles in goal-directed behavior. Self-regulation enables students to establish goals, devise strategies, monitor progress, and make necessary adjustments to achieve desired outcomes. Executive functioning provides the cognitive flexibility and working memory capacity required to carry out these goal-directed behaviors (Follmer & Sperling, 2016).

Emotional regulation is another area where self-regulation and executive functioning entwine. Self-regulation involves recognizing and managing emotions, while executive functioning facilitates adaptive emotional responses through processes such as emotional working memory and cognitive reappraisal (Xiu et al., 2018). Entwined self-regulation and executive functioning are crucial for self-initiated, proactive learning behaviors. Students in STEAM education settings with strong self-regulation skills are more likely to exhibit intrinsic motivation, initiative, and goal-directed behavior, all of which are facilitated by executive functioning abilities such as cognitive flexibility, working memory, and inhibitory control (Dong et al., 2023; Gu & Zhu, 2023). By nurturing and developing self-regulation and executive functioning skills, educators can empower students to effectively manage their thoughts, emotions, and behaviors, leading to improved academic achievement and overall well-being (Figure 5).

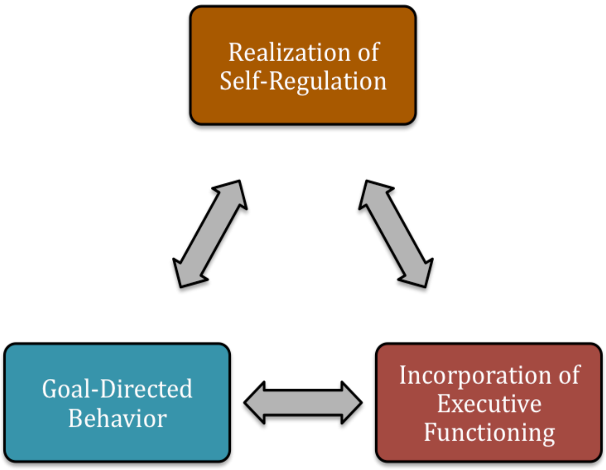

Figure 5. Entwined art of learning

Typification of Theory

According to Vygotsky's *Sociocultural Theory of Cognitive Developmen*t (1978), self-regulation involves both individual and social learning aspects. Social interactions serve as models that internalize the cognitive and metacognitive processes of self-regulation, fostering co-regulation in learners (McCaslin, 2009). When students are supported in reaching emotional goals they are empowered to attain their cognitive, emotional, and social objectives, while also facilitating independent learning, inquiry, and the construction of knowledge systems (Zhu & Atompag, 2023). Constructivism fosters active student engagement, hands-on experiences, and integrated teaching and learning in STEM and STEAM educational settings and enables students to construct their own understanding and participating in authentic, self-directed learning experiences (Videla et al., 2021).

The concept of socially shared regulation goes beyond co-regulation, indicating the regulation of shared learning goals within groups (Hadwin et al., 2017). Essential components of Self-Regulated Learning (SRL) include metacognition regarding experiences, knowledge, and control, as highlighted by Zimmerman (2008). SRL involves the interplay between metacognition and affect, with students' emotional experiences and motivation influencing their metacognitive control decisions (Efklides & Metallidou, 2020). Casali et al. (2022) assert that the integrated Self-Regulated Learning (iSRL) model posits that academic learning encompasses cognitive, behavioral, and emotional outcomes. These outcomes comprise achievements in academics, adoption of effective study behaviors, and regulation of emotions. The iSRL model emphasizes the role of internal factors within individuals, such as self-regulated learning, motivation, personal skills, and genetics, in facilitating successful academic learning. These internal factors interact with external systems, including families and institutions, to shape the processes and strategies employed in academic learning.

Flexibility in utilizing these internal factors is posited by the iSRL model to be a critical factor in achieving positive outcomes in an academic journey. The ability to adapt and employ self-regulated learning strategies contributes to the development of a resilient and adaptable learner who can effectively navigate the complexities of the educational environment. STEAM education nurtures emotional intelligence, which is crucial for cultivating critical and creative thinking in students and for self-regulation. Entwined STEAM learning enables students to participate in activities that encourage empathy, teamwork, and self-regulation, which contributes to student actualization (de Vries, 2021). Supporting SRL is of significant importance as it aligns with contemporary educational initiatives and advancements, such as 21st-century learning, inquiry learning, inclusion, and assessment for learning (Perry et al., 2018). SRL promotes the cultivation of adaptive, lifelong learners who possess critical thinking and problem-solving skills. These learners are equipped with the capacity to learn and work both independently and collaboratively, enhancing their ability to thrive in diverse educational contexts.

Application of Theory

According to Self-Determination Theory (SDT), an individual's motives for their behavior are intricately linked to their level of engagement and overall well-being. Individuals who pursue their genuine interests and values tend to exhibit greater vitality and overall health (Ryan & Deci, 2000). However, for individuals to maintain this level of autonomy and self-determination, their environment must satisfy their basic needs for autonomy, competence, and relatedness. While promoting competence and relatedness can encourage the internalization of a behavior or value, they are insufficient in facilitating integration, a critical aspect of authentic self-regulation (Deci & Ryan, 1985; Grolnick & Ryan, 1989; Ryan & Deci, 2000). For integration to occur, individuals require the freedom to reflect on and endorse their motivations and regulations and align them with their self-identity, thereby fulfilling their need for autonomy. STEAM learning environments that enable students to control their learning create conditions such that they develop an interest in learning and thus actualizing SDT. Providing conditions for students to maintain autonomy presents learners with an environment conducive to integration and self-regulation. Relational-rich STEAM learning settings afford students constructivist, experiential learning for reflection and motivation for autonomy through socially and emotionally supportive environments.

Representation of Theory

A meaningful connection can be made between SRL theory and the practice of mindfulness. Mindfulness-based interventions have been shown to improve self-regulated learning skills (McKeering & Hwang, 2019). Mindfulness practice is strongly related to self-regulated learning, as it enhances students' ability to focus their attention on the task at hand, regulate emotions, and adapt strategies as needed. Self-regulated learning in STEAM learning environments fosters student resiliency and adaptability for self-efficacy. Applying mindfulness in an academic setting such as STEAM aligns with the philosophical principles of providing an experiential learning environment for students to actualize cognizance of thoughts and emotions for regulating learning and academic, social, emotional, and behavioral success (Figure 6).

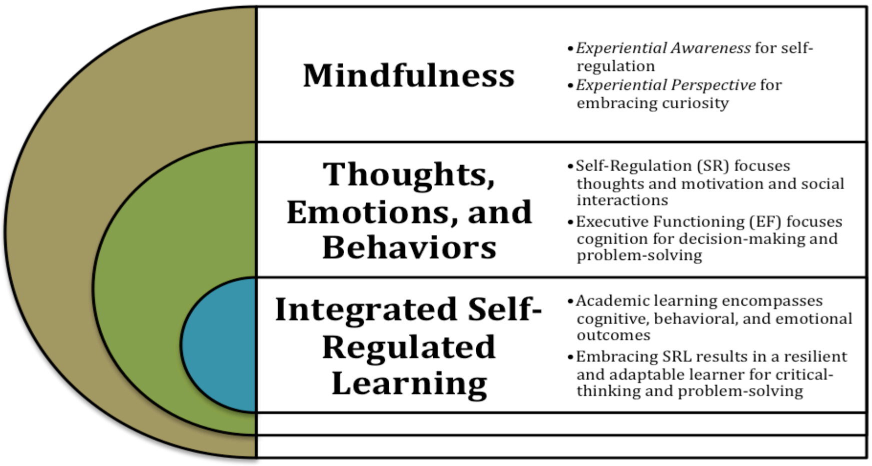

Figure 6. Mindfulness for connecting theory to application

Theoretical Framework

STEAM Learning Environment

Art encourages students to think creatively and imaginatively, which is essential for addressing complex, real-world problems in a transdisciplinary context (Clark & Button, 2011). STEAM fosters confidence in students by providing opportunities to engage in practical, multidisciplinary learning activities. These experiences empower students to apply their skills across diverse fields, fostering a sense of proficiency and self-assurance (Rikoon et al., 2018). STEAM learning environments that capitalize on student self-regulation and mindfulness create conditions for students to build social capital through constructivist, cooperative learning for actualizing resiliency and adaptability for inquisitiveness, creativity, and problem-solving. In STEAM, enhanced social capital contributes to improved STEAM learning, motivation, and participation among students. This is achieved by providing emotional resources within students' social networks (Saw, 2020). Prosocial communications, self-management, and actualization motivate learners and provide opportunities for engaging in both critical thinking and creative thinking. Emotional awareness, motivation, and social recognition play crucial roles in shaping students' academic success in STEAM and their social and emotional learning (Li et al., 2022). Cognitive and emotive experiential learning entwine in STEAM for self-regulation and self-regulation for mindfulness (Figure 7).

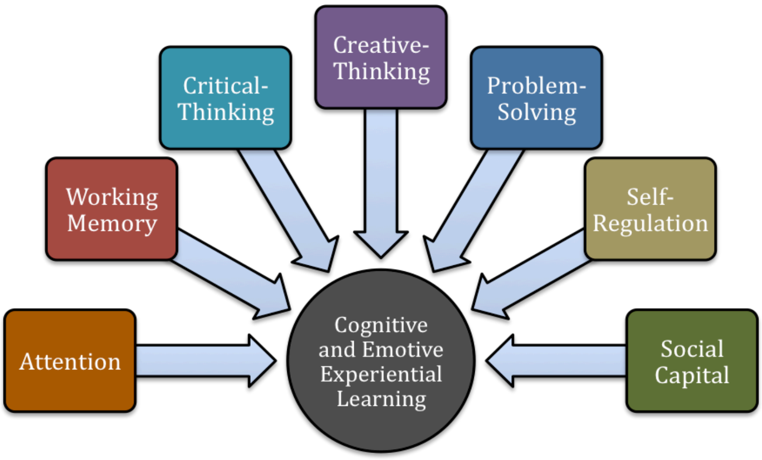

Figure 7. Entwined STEAM and mindfulness

Mindfulness for Academic Achievement

Executive functioning is a critical cognitive foundation that plays a crucial role in student success. Executive functioning consists of essential cognitive skills, such as working memory, cognitive flexibility, inhibitory control, planning, and self-monitoring, which provide students with the tools needed to regulate their thoughts, actions, and emotions, ultimately facilitating task completion (Lam & Seiden, 2020; Qi, 2023). Possessing strong executive function skills can lead to academic and social success for students (Andreu et al., 2023; Senter et al., 2023; Valero et al., 2022). Research has shown that executive function skills are significantly related to children's learning abilities, with implications for subjects such as literacy and mathematics (Chan et al., 2022; Delisio et al., 2023; Yousefi et al., 2023). An effective strategy for promoting academic success is mindfulness, which can enhance self-regulation skills. By improving self-regulation skills, students can better focus their attention on academic tasks, resist distractions, and manage time efficiently, which are all key components of executive functioning. Mindfulness not only fosters cognitive skills such as attention, working memory, and self-regulation, but also reinforces social-emotional competencies, allowing students to better manage emotions, build constructive relationships, and make responsible decisions (Ahmed Aboalola, 2023; Day et al., 2022; Qi, 2023).

Mindfulness for Social and Behavioral Success

Mindfulness-based interventions are commonly implemented in educational settings to target social-emotional development and promote emotional and behavioral regulation (Phan et al., 2022). Neurological and psychological research supports the integration of mindfulness-based strategies in STEAM, highlighting the potential benefits of such interventions. Zenner et al.

(2014) conducted a comprehensive analysis of mindfulness interventions in educational settings and found that these initiatives yielded significant improvements in cognitive functioning and resilience to stress. Furthermore, they observed a notable reduction in symptoms of depression, anxiety, and stress. Providing executive function training to children is considered a preventive measure for mental disorders, with approaches encompassing behavioral, movement-based, and mindfulness methodologies (Goldberg et al., 2022; Gupta & Lee, 2020; MacDonald & Neville, 2022). Behavioral training has also demonstrated effectiveness in addressing attention deficits among children (Lee et al., 2022). Mindfulness training, with its emphasis on non-judgmental experiences of thoughts, feelings, and actions in the present moment, has been shown to reduce stress and anxiety while enhancing cognitive control (Duarte et al., 2022; Felver et al., 2017; Sousa et al., 2021).

CONCLUSION

STEAM is a philosophical catalyst for entwining interdisciplinary and transdisciplinary learning, both within and beyond its acronym, promoting comprehensive, holistic learning. By incorporating the arts, STEAM offers diverse paths for students to participate in collaborative learning, fostering creativity and inquiry for academic growth and mindful, emotional learning. The philosophy of mindfulness centers around the belief that individuals can achieve a deeper understanding of their minds and behavior through intentional and non-judgmental awareness. Both mindfulness and STEAM create supportive social environments for students to cultivate awareness of their thoughts, emotions, and sensory experiences.

STEAM learning influences students' emotions and fosters an environment that cultivates emotional awareness. Entwined cognitive, social, emotional, behavioral, and mindful learning in STEAM education equips students with essential skills to pursue lifelong academic success and mindfulness for collaborating with others. Emotional awareness empowers learners to build cognitive and affective social capital, facilitating teamwork and effective problem-solving. STEAM not only nurtures emotional awareness but it also encourages its application in regulated inquiry, critical thinking, and problem-solving, enhancing students' overall academic and mindfulness abilities.

STEAM ignites student curiosity and inquiry, promoting collaborative learning, emotional regulation, and active engagement. By entwining the arts, STEAM offers unique ways to engage emotions, influencing both cognitive and emotional aspects of education. Personalized learning enhances academic outcomes and helps regulate emotions, creating meaningful sensory experiences. The arts in STEAM contribute to a sensory-rich, collaborative learning environment, fostering critical thinking, creativity, and active learning. The entwined philosophies of mindfulness and STEAM guide experiential learning in cognitive domains for problem-solving, as well as the mindfulness domains of experiential awareness for self-regulation and experiential perspective for embracing curiosity. Entwined mindfulness and STEAM philosophy pave pathways for students to engage in cognitive and emotive experiential learning for attention, working memory, critical thinking, creative thinking, problem-solving, self-regulation, and building social capital.

Cultivating social and emotional skills through STEAM experiential learning, coupled with experiential awareness and experiential perspective for mindfulness, equips students with tools for self-regulating and focusing attention for executive functioning and attaining goals. Collectively, these skills empower students to organize thoughts, plan tasks, prioritize, solve problems, make sound decisions, and regulate behavior. Executive functioning skills significantly contribute to academic success, personal growth, and overall well-being, which lead to goal-directed lifelong learning. STEAM builds student confidence by providing hands-on, interdisciplinary, and transdisciplinary learning opportunities. Blending cognitive and emotional experiential learning intertwines STEAM with self-regulation and mindfulness. Entwining mindfulness-based strategies in STEAM creates conditions and an atmosphere for students to engage in meaningful academic, social, emotional, and behavioral lifelong learning.

Recommendations

The researchers provided rationale for entwining self-regulation and mindfulness strategies alongside STEAM curricular delivery to provide holistic learning for students. A STEAM construct naturally creates opportunities for students to engage in social capital-building due to the collaborative nature of STEAM learning. In addition, STEAM learning environments naturally create an atmosphere for students to engage in emotive learning, thereby providing students with opportunities to capitalize on emotional awareness for self-regulation and mindfulness. The researchers recommend incorporating mindfulness exercises, such as diaphragmatic breathing to create emotional and physical awareness (body scans). These activities aid in increasing the student's self-awareness and focus on the present moment, thus mentally preparing them to participate in STEAM activities.

Furthermore, the researchers recommend that teachers capitalize on the social, emotional, and behavioral learning that takes place, in addition to academic learning, through STEAM education. The social, emotional, and behavioral benefits of STEAM include opportunities to better promote the self-efficacy beliefs of learners. By integrating mindfulness activities in the context of STEAM education, educators can empower students to develop greater self-efficacy and increased confidence and competence in their own STEAM abilities. Supporting the self-efficacy beliefs of learners can be accomplished by affording opportunities for students to reflect on their progress, set goals, and celebrate their success, thus increasing their confidence in their ability to excel in STEAM. Emotionally connecting students to academic content facilitates ownership of the learning and motivates students to succeed. A natural relationship exists between STEAM learning and mindfulness that most STEAM educators traditionally overlook. While student academics are essential, the potential for entwining student self-actualization and self-regulation exists because of the inquisitive, creative, and emotive qualities of STEAM education. Capitalizing on this entwined relationship does not modify curricular content, but it does modify the ways learners think in order to improve student self-efficacy, which promotes holistic learning.

Teachers also require opportunities to grow professionally and advance skills to support students better. STEAM teachers are also highly skilled in delivering interdisciplinary and transdisciplinary instructional delivery for cognition, but providing professional insight regarding the social, emotional, and behavioral benefits of STEAM learning, alongside self-regulation and mindfulness, provides STEAM teachers with transferable skills to aid all students. Rather than simply engaging in episodic professional development or periodic professional learning, the researchers recommend employing professional erudition, which is an amalgamation of targeted professional learning and development for site-based professional growth. Professional erudition is a form of STEAM-based professional growth that affords educators a continuous and evolving process for supporting students' academic and self-regulatory needs. In a study conducted by Dignam (2023), employing professional erudition in STEAM resulted in students developing both improved STEAM-related academic achievement as well as improved social-emotional growth, actualization, and efficacy. The researchers recommend providing teachers with professional growth opportunities through a professional erudite lens, as professional erudition is a strategy that employs multiple professional growth pathways. Entwined site-based professional development, targeted professional development, and professional learning via professional erudition create meaningful, targeted professional growth to support STEAM education and mindfulness.

Lastly, the researchers recommend that educators capitalize on the experiential learning relationships that exist between and within STEAM education and mindfulness. The discernment of social and emotional skills development as a result of STEAM experiential learning, alongside the experiential awareness and experiential perspective of mindfulness, provides students with skills for self-regulating, focusing attention, employing executive functioning, and attaining goals. A primary objective and intention of education is to equip students with skills and tools they can employ throughout a lifetime of learning. Entwined cognition and emotional, experiential learning, awareness, and perspective create holistic learning for a lifetime of application. Entwining STEAM education, self-regulation, and mindfulness affords students adaptable skills for lifelong learning.

DECLARATIONS

Ethical Considerations: This study did not require ethics committee approval or informed consent because it did not involve human participants. All research methods were conducted in accordance with institutional guidelines and applicable laws.

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Data Availability Statement: The data utilized in this study are publicly available and were used by the authors for constructing original STEAM and mindfulness theory and practices for use by educators and clinicians. Specific sources of the data are included as in-text citations and can be accessed through the links and DOIs within the References section.

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