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Investigation of Turkish and Turkmenistanian Students' Approaches towards Environmental Ethics and Their Levels of Naturalistic Intelligence

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Abstract

The purpose of this study is to compare the attitudes of Turkmenistanian and Turkish university students towards environmental ethics approaches and their naturalistic intelligence (NI) field. In addition, it was investigated whether there is a gender difference in environmental ethics levels in both countries students'. Environmental Ethics Attitude Scale (EEAS) and Multiple Intelligence Areas Inventory were applied to the students. A total of 172 Turkish and 103 Turkmenistanian university students participated. A significant difference between the mean scores of Turkish and Turkmenistanian was observed in all four categories of environmental ethics [Anthropocentric, Ecocentric, Ecofeminism, Teocentric]. The analyses conducted to test gender differences showed that there was not a significant difference between male and female Turkmenistanian students' EAA mean scores. Comparison of NI levels of students from both countries suggested that Turkish students' NI levels were "developed" and Turkmenistanian students' NI levels were "moderately developed". The research findings were considered for both countries students'.

Introduction

Human beings have long been competing with the nature in their struggle to continue their existence. They are in constant interaction with both living creatures and the abiotic environment. These points validate asking the following question: Do we have a healthy relationship with the environment? If we consider the recent past, the answer is: No. Many resources have been depleted; pollution increased, and -as a result- global warming started causing the emergence of many environmental problems. In fact, the human race is currently busy trying to find solutions to the resulting problems. This is because those problems made human beings realize that they need to protect the environment, strengthened their sense of responsibility towards the nature, and contributed to the development of environmental ethics.

Environmental ethics is a tool that deals with the moral aspects of the relationship between human beings and the environment, and presents the methods necessary to protect it (Des Jardins, 2006). The fact that environmental problems globally affect the whole world highlights the importance of raising individuals who have high awareness and knowledge of their environment and the need to approach those problems in line with ethical values (Kayaer, 2019). This is the only way that those problems can be solved and future problems be avoided (Gürbüzoğlu-Yalmancı, 2015). The source of environmental problems is considered to be people's activities which aim for economic development, but, in doing so, ignore environmental ethics (Wilkinson, 2002). As environmental threats that emerged following aspirations for continuous growth and consumption at the end of the 18th and 19th centuries have started to be perceived as problems, many people started to discuss human-environment relationship which resulted in the development of various environmental ethics approaches (EEA) (Des Jardin, 2006). There three main EEAs: (1) the anthropocentric approach, (2) the biocentric approach, and (3) the ecocentric approach.

The anthropocentric approach has developed in line with the views of scientists and philosophers such as Aristo, Descartes, Newton, and Bacon. Descartes (1994) underlined the need for human beings to embrace and rule the environment and laid the foundations of this philosophy. According to this approach, human beings intrinsically value things that they consider to be useful to them (Lundmark, 2007). The environment should be protected because if it is not then people will suffer. Therefore, protection of natural resources is prioritised so that the life quality of people would not deteriorate (Callicott & Frodeman, 2009; Dunlap & Van Liere, 1978). Biocentric approach, on the other hand, advocates the idea that not only humans but also other living creatures are important (Des Jardins, 2006). This approach argues that humans should not be considered to be superior to the environment and that each living creature in the environment is important. As for the ecocentric approach, it has

been formed based on the ideas of scientists such as Leopold and Naess. Ertan (2004) stated that this approach advocates the idea that both living creatures and inanimate objects, thus, the whole environment is important.

In addition to the above approaches, there are other environmental ethics approaches such as animal welfare ethics, deep ecology, soil ethics, teocentric environmental ethics, sustainable development ethics, postmodern environmental ethics, ecofeminism, respect to the nature ethics, earth ethics, and ecological ethics (Mahmutoğlu 2009; Rolston, 2003).

While these ethical approaches facilitate the learning of environmental values, the tuition provided via the ideas affected by these approaches enable individuals to develop knowledge, attitudes, and behaviours that make them more aware of the nature (Uygun, 2006). Learning about environmental values help learners develop positive environmental attitudes and this situation results in environmental behaviour (Homer & Kahle, 1988). This process also affects the way learners make decisions about topics relating to the environments (Scott & Oulton, 1998). Naturally positive environmental behaviours develop through environmental ethics and related teaching implementations which can increase students'' awareness of and interest in their environment.

Based on the idea that individuals have different ways of thinking and problem solving skills, Howard Gardner developed the Multiple Intelligences Theory (MIT). According to Gardner (2004) there are eight different domains of intelligence that individuals can possess. Those domains of intelligence are; visual-spatial, logical-mathematical, bodily-kinaesthetic, musical-rhythmic, verbal-linguistic, social-intrapersonal, interpersonal, and naturalistic intelligence. Individuals have various talents that are different from the talents others possess and those are referred to as intelligence types (Gardner, 2006, 2007). MIT states that there are eight domains of intelligence; however, individuals may possess different domains of intelligence at high levels and others at low levels (Stanford, 2003). People who have developed Naturalistic Intelligence (NI) are sensitive towards events in the nature; interested in nature trips; curious about ecology, plants, and animals; willing to protect the environment; interested in seasons and climate events; participate in projects relating to the nature; and develop an awareness of the nature (Saban, 2002). Therefore, such individuals are expected to be more successful in developing behaviours towards the environment, environmental values, and environmental ethics.

Analysing related literature on environmental ethics suggest that there is a strong relationship between environmental behaviour and environmental attitudes, those who exhibit environmental behaviour were also found to have high scores for environmental attitudes (i.e. Halkos & Matsiori, 2017). Gribben and Fagan (2016), who correlated anthropocentric attitudes and climate change, highlighted the importance of universities in disseminating the awareness that climate change resulted from anthropocentric approaches. They also noted the importance of ecology-centered attitudes. In their study investigating science and biology teachers' environmental ethics awareness levels, Karakaya and Yılmaz (2017) identified that there were significant differences between science teachers' environmental ethics awareness levels in terms of gender and type of school that they worked in. The study conducted by Quinna, Castéra and Clément (2016) which investigated the meaning Australian teachers attached to anthropocentrism and non-anthropocentrism found that answers indicating a negative attitude were generally related to anthropocentricism. Gola (2017) content analysed which of the environmental ethics approaches (anthropocentric, biocentric, or holistic) were dominant in the coursebooks utilized in the 4th grade in Polish schools. The results showed that the anthropocentric ethical approach was dominant. Gerçek (2016) investigated university students' perceptions of environmental ethics and concluded that the students' perceptions were at a medium level and there was not a significant difference between participants in terms of gender or year of study. While Alagöz and Akman (2016) investigated whether pre-service teachers followed an anthropocentric or ecocentric approach in solving environment related problems, Jackson et al. (2016) studied students' environmental attitudes and behaviours in two public and two international schools in Hong-Kong. The results showed that there was not a significant difference between students' attitudes or behaviours in terms of school type. In another study, Erten (2012) compared Azeri and Turkish university students' environmental awareness levels and it was found that Turkish students' knowledge, attitudes, and behaviours regarding the environment were higher. Chuvieco, Burgui-Burgui, Da Silva, Hussein, and Alkaabi (2018) investigated environmental sustainability habits of university students in Spain, Brazil, and United Arab Emirates, the results, however, did not indicate any significant differences between countries. On the other hand, Berglund, Gericke, Boeve-de Pauw, Olsson, and Chang (2019) compared Taiwanese and Swedish students' sustainability awareness and found significant differences. Swedish students' sustainability awareness is higher than Taiwan students. Furthermore, the number of studies conducted on environmental ethics has increased in recent years in line with increases in environmental problems.

An investigation of studies on multiple intelligence theory suggests that there are many studies conducted by Furnham and colleagues which aimed to predict the intelligence domains of students in different countries (i.e.

America, England, Japan, Iran, East Timor, and Portugal). Students in these studies were asked to predict which domains of intelligence they, their parents', and siblings possessed by answering researchers' questions and the findings were evaluated taking into account the cultural aspects of the countries that the participants were from (Furnham, Hosoe, & Tang, 2001; Furnham, Shahidi & Baluch, 2002; Neto, Furnham, & da Conceição Pinto, 2009). Furnham, Hosoe, and Tang (2001) asked American, English, and Japanese students to estimate their own, parents, and siblings' multiple IQ scores (grouped under verbal, numerical and cultural factors). While American students made higher estimations compared to Japanese, all students reported higher numerical IQ values for their fathers and brothers, and higher verbal IQ values for their mothers and sisters. In a different study, Furnham, Shahidi and Baluch (2002) asked English and Iranian students to estimate multiple intelligence scores of their own, their parents, and siblings. They found that Iraninan students had higher levels of tendency to accept gender and race differences. In a similar study, Neto, Furnham, and Conceição Pinto (2009) found that students from East Timor and Portugal reported higher scores for their fathers in all types of intelligences when compared to the scores reported for their mothers. And, Portuguese students were found to have higher levels of sense of self.

There are a limited number of studies in which environment, environmental ethics, and MIT have been studied. Baş (2010) compared the effects of MIT-based and traditional teaching approaches in terms of their impact on students' environmental awareness and attitudes and found that MIT-based activities are more effective in increasing students' environmental awareness and developing positive attitudes. With regards to NI, Baş (2010) stated that school garden visits and activities where students planted trees had positive impacts on developing students' attitudes towards the nature. Similarly, Okur, Yalçın Özdilek and Sezer (2012) compared naturalistic intelligence of women with their environmental attitudes and concluded that naturalistic intelligence is a significant predictor of environmental attitudes. Sangsongfa and Rawang (2016) integrated environmental education and communicative English teaching focusing on MIT and found that the administration of their model increased students' academic achievement. Yenice, Özden and Alpak Tunç (2016) compared pre-service science teachers' environmental attitudes with the domains of multiple intelligence and found logical-mathematical intelligence, bodily-kinaesthetic intelligence, and naturalistic intelligence to be determinants of environmental attitudes. They considered logical-mathematical intelligence in terms of the nature creating an order and expected those who have high levels of logical-mathematical intelligence to have the skills to question and evaluate the nature. Similarly, they considered bodily-kinaesthetic intelligence and naturalistic intelligence as determinants of attitudes towards the nature since the former would require development of psychomotor abilities to protect the nature and the latter would require the development of the ability to empathise with the nature. In the light of the literature, it is understood that the results of studies conducted interculturally and internationally are important for the environment, environmental ethics, and multiple intelligences theory (i.e. Chuvieco, Burgui-Burgui, Da Silva, Hussein, & Alkaabi, 2018; Berglund, Gericke, Boeve-de Pauw, Olsson, & Chang, 2019; Neto, Furnham, & da Conceição Pinto, 2009).

Various socio-economic and cultural structures form a basis for important comparisons. The conversations held with students who took environment and biology courses at the university indicated that there were differences between students' NI levels and environmental ethics perceptions. Moreover, it has been observed that there were opinion differences between Turkmenistanian and Turkish students from time to time, but there were also points that both groups of students agreed on. This situation has drawn the attention of the researchers' attention and analysis of related literature suggested that there were a limited number of studies investigating multiple intelligences theory and environmental ethics, thus, it is considered that this niche in the literature should be filled. In line with this, the present study aims to compare the domain of naturalistic intelligence and environmental ethics perceptions that Turkmenistanian students (those who moved to Turkey for their studies) and Turkish students possess.

Globalization lead to an increased importance given to higher education to broaden students' horizons in an effort to train individuals as world citizens. And, experiencing different values and utilizing various opportunities through international education has been defined as one of the prerequisites of reaching this goal. Student exchanges are one of the most frequently occurring examples of international education (Foreign Economic Relations Board [FERB], 2013). The term "international student" is used to describe students who study part of or their whole study period in a country where they do not have citizenship of ("The Power of International Education", 2021). Such students leave their country of citizenship and travel abroad to realize international exchanges. Most of the international students visiting Turkey for such exchanges come from central Asian countries. Among those countries, Turkmenistan has the first place (Foreign Economic Relations Board [FERB], 2013). Therefore, it is assumed that Turkmenistanian students are among the students with whom Turkish students have the most interaction and sharing in terms of science, education, culture, and art. In this sense, comparing students from these two countries in terms of environmental ethics and naturalistic

intelligence can provide valuable information regarding ethical understanding and how any proposed solution strategy can impact on naturalistic intelligence characteristics. Since students from both countries have spent a considerable amount of time in their home countries, they are considered to have had enough experience to learn about their home cultures and education systems. Therefore, the fact that the compared students are studying in the same Turkish higher education institution does not affect the international nature of the tuition.

The Education System in Turkey and Turkmenistan

The education system of Turkmenistan -which left the Soviet Union and declared its independence- includes pre-school, elementary school, secondary-high school, and higher education. Compulsory education is 12 years and consists of four years of elementary school tuition and eight (six + two) years of secondary-high school tuition. Elementary school tuition (1st, 2nd, 3rd, and 4th years) equips students with basic skills such as literacy and mathematics, and it also includes tuition on nature knowledge (Ashgabat Education Consultancy (AEC), 2013). High school tuition is two years and there are three main areas of studies (Physics-Mathematics, Natural Sciences, and Social Sciences) which include courses such as the Turkmenistanian language, social and natural sciences, foreign languages, sports, and arts (Gelişli & Beisenbaeva, 2017). Undergraduate tuition, on the other hand, is five years long. Vocational courses have been taken out of the basic curriculum and replaced by social sciences and physical education courses that aim to equip learners with basic knowledge on law, ethics, economy, politics, environmental problems, and culture. It has been observed that teenagers prefer to study in undergraduate programs related to underground resources and petrol-natural gas, and energy (AEC, 2013). The education system is based on the basic principles of democracy, national identity awareness, and respect towards other people and nations (UNESCO, 2011).

Similarly, compulsory education in Turkey is 12 years. This compulsory education has three levels each of which is four years long: elementary, secondary, and high school. The system is based on the constructivist approach and coursebooks are prepared accordingly. The curriculum avoids rote learning and prioritizes individual differences. Attention is paid to ensure that the courses are applicable in daily life and students are encouraged to do research. The aims of primary school (elementary + secondary) tuition include the following learning objectives in relation to the environment: exploring the nature and understanding the relationship between humans and the nature, creating an interest and curiosity regarding the events taking place in individuals' immediate environment, and developing positive attitudes towards the environment. The high school biology curriculum includes topics such as the world of living creatures, ecosystem ecology, current environmental problems, community and population ecology (Ministry of National Education [MoNE], 2019). Environment related departments in the Turkish higher education are not generally preferred by students and such programs remain to be at the bottom of the lists. Students rather prefer studying in health related programs (see Council of Higher Education (CoHE) Guide, 2019]

Research Questions

Universities' opinions regarding topics such as cultural interaction, international collaboration, competition, and multicultural education -which emerged as a result of globalization- are affective at the international scale (Küçükcan & Gür, 2009). The fact that environmental problems affected the world at a global scale has had various impacts in individuals' attitudes towards the nature and increased the motivation to search for different solutions and, consequently, various environmental ethics approaches have emerged. Identifying the similarities or differences between countries in terms of environmental ethics approaches is significant since it can present various solution strategies and/or views developed to combat environmental problems. Evaluating solution strategies and ideas during teaching/learning processes can increase awareness of environmental ethics and contribute towards materializing the developed ideas and solution strategies. In relation to that, MIT is significant since it prioritizes individual differences and product yielding capacity in different cultures as explained in Gardner's (1983) definition of intelligence. In particular, identifying NI levels of individuals from different cultures would not only provide information about the education style of that culture but also reveal those individuals' interest in the nature. In addition, identifying intercultural sex differences in terms of environmental ethics approaches can reveal the societal role of gender at the international level. Considering the above mentioned aspects, the following research problems were created within the general theme of investigating the relationship between environmental ethics and naturalistic intelligence. The main research question was: "Is there a significant difference between Turkish and Turkmenistanian students in terms of environmental ethics attitudes and NI levels?"
The sub research questions were:

(1) Is there any relationship between environmental ethics and NI?
(2) Is there a significant difference between Turkish and Turkmenistanian students' perceived levels of environmental ethics?
(3) Is there a significant difference between Turkish and Turkmenistanian students' NI levels?
(4) Is there a significant difference between Turkish and Turkmenistanian students' environmental ethics levels in terms of the gender variable?

Method

Turkish and Turkmenistanian university students' environmental ethical attitudes were compared in terms of their naturalistic intelligence in the present. Survey model, a quantitative research method, was utilized in the study. The dependent variables that were compared in the study were the two groups of university students. The independent variables that were examined, on the other hand, were environmental ethics attitudes and naturalistic intelligence levels as well as gender.

Sampling

The study sample in this study consisted of Turkish and Turkmenistanian students who studied at Kafkas University in Turkey. 275 students (172 Turkish and 103 Turkmenistanian) participated in the study. The data were collected using the Environmental Ethical Attitude Scale and Multiple Intelligence Domains Inventory. Students were informed about the study and the data was collected from students who volunteered to participate. Students have come across environment related courses and topics at certain periods of their tuition. In this sense, it was considered that they would have developed a certain level of environmental ethical attitudes and naturalistic intelligence up to that point in their education. Therefore, variables such as year of study and study program were ignored. Demographic characteristics of the participants are detailed in Table 1.

Table 1. Demographic characteristics of the participants

Group	Gender	N	Total
Turkish	Female	105	172
	Male	67	
Turkmenistanian	Female	58	103
	Male	45	

Instruments

Environmental Ethical Attitude Scale

The Environmental Ethical Attitude Scale (EEAS) developed by Gürbüzoğlu-Yalmancı (2015) was utilized to measure environmental ethical attitudes (EEA) of Turkish and Turkmenistanian students. Kaiser Meyer Olkin (KMO) value of the scale is 0.837 and the chi-square value obtained from Bartlett's Sphericity test is significant ($\chi 2$= 11920.99; $p<.05$). Answers to the questions in the scale are evaluated on a 5-point Likert scale. There are a total of 33 questions under four scales [Anthropocentric (first factor), Ecocentric (second factor), Ecofeminist (third factor), and Teocentric (fourth factor) environmental ethics]. Total variance explained by those factors is 47,57 %. Factor loadings of the items under the first factor range between .958 and .828, between .579 and .333 for the items under the second factor, between .866 and .482 for the items under the third factor, and between .805 and .724 for the items under the fourth factor. The threshold limit for factor loadings is generally accepted to be .30 and above (Hair Junior, etc., 1998; Merenda, 1997; Tabachnick, & Fidell, 1996). Cronbach's Alpha reliability coefficient for the first factor is calculated as .80, .72 for the second, .82 for the third, and .87 for the fourth factor. The Confirmatory Factor Analysis (CFA) supported and confirmed the four-factor solution achieved ($\chi 2$/df=2.42, RMSEA=.059, GFI=.84, CFI=.95, NFI= .92, NNFI=.94 ve AGFI=.82).

CFA Results for the Environmental Ethical Attitude Scale

CFA, which was conducted to confirm the construct validity of EEAS in its administration with Turkish and Turkmenistanian students, suggested that the first question under the Anthropocentric ethic approach had a low "t" value and its predictive power was low, thus, this item was deleted in EEAS's administration in the present

study. The remaining 32 items were analysed to measure fit indices and the results suggested that the model had a good fit ($\chi 2$=763.71, df= 458, p = 0.00, $\chi 2$/df= 1.66, RMSA=.049, NFI=.94, NNFI=.97, CFI=.97, IFI=.97; Schermelleh-Engel, Moosbrugger & Müller, 2003; Ullman, 2001) and, thus, the scale was used to measure participants' environmental ethics attitudes.

Example statements for each factor included: "The nature exists for human beings" for the Anthropocentric approach, "Each living creature in the nature has the same value" for the Ecocentric approach, "Gender discrimination should be avoided when solving environmental problems" for the Ecofeminist approach, and "All the creatures that god created should be loved" for the Teocentric approach.

Multiple Intelligence Domains Inventory

Multiple Intelligence Domains for Educators Inventory was used to determine Turkish and Turkmenistanian students' naturalistic intelligence (NI) levels. The inventory was first developed by Armstrong (1994). The present study utilized the version of the inventory revised by Saban (2002). Each item in the inventory included the following anchors; "not appropriate at all", "not appropriate", "partially appropriate", "appropriate", "totally appropriate". Cronbach's alpha reliability coefficient in the original inventory was .83 and the coefficient in the present study was .80. This indicated that the inventory had a good level of internal consistency. Answers to the items in the inventory are collected on a five-point Likert scale. There are 10 items for each intelligence domain. In line with the aim of the study, only the items prepared to measure the NI domain were used. Participant scores were evaluated based on the following; scores between 32 and 40 were considered as "very developed", 24-31 as "developed", 16-23 as "moderately developed", 8-15 as "somewhat developed", and 0-7 as "underdeveloped".

Data Analysis and Procedures

The data in this study consisted of the answers Turkish and Turkmenistanian students gave to the questions within the "Environmental Ethical Attitude Scale (EEAS)" and "Multiple Intelligence Domains Inventory". Prior to data collection, the questions within the scales were checked in terms of being comprehensible for students. Comprehensibility is one of the factors that increase reliability of the scale items. There are Turkmenistanian students who pursue their education in Turkey and their Turkish levels are determined by the Turkish Teaching Application and Research Centre (TTARC) within the university and Turkish language courses are provided to those who need language support. Therefore, when they start their tuition, both Turkish and Turkmenistanian students understand Turkish. Nevertheless, a pilot study was administered to 10 students from each group in order to ensure that both Turkish and Turkmenistanian students understood the questions. The results of the pilot administration suggested that there were no questions which were incomprehensible for either group of students. The construct validity of the EEAS scale was established via CFA. Following this step, ANOVA was conducted to test whether there were NI level and environmental ethics attitude differences between Turkish and Turkmenistanian students who were brought up in a different culture and education system. MANOVA was conducted to test whether there were gender related differences.

Results and Discussion

Relationship between NI and EEA

According to Table 2, the highest level of relationship was observed between NI and ecocentric and teocentric versions of EEA. The relationship between NI and ecofeminist ethic was moderate and a low and negative relationship was observed between NI and anthropocentric ethic. Individuals with high levels of NI give importance to understanding global environmental problems (Mauladin, 2013). Similarly, the underlying rationale for environmental ethics is to develop a holistic solution to environmental problems through an ecocentric perspective.

Table 2. Correlation results between NI and EEA

	Anthropocentric ethic	Ecocentric ethic	Ecofeminist ethic	Teocentric ethic
NI	-.15*	.49**	.27**	.41**

**Correlation is significant at the 0.01 level (2-tailed)

EEA Differences between Turkish and Turkmenistanian Students

ANOVA and descriptive statistics were utilized in order to confirm whether there was a difference between Turkish and Turkmenistanian students' EEAs (Table 3).

Table 3. ANOVA results for comparison of Turkish and Turkmenistanian students' EAAs

Ethical approach	Group	N	Mean	sd	df	Chi-square	F	p
Anthropocentric ethic	Turkish	172	6.11	2.49	1	0.40	188.69	.00
	Turkmenistanian	103	9.92	1.67	273			
Ecocentric ethic	Turkish	172	71.34	8.94	1	0.32	130.54	.00
	Turkmenistanian	103	57.90	10.22	273			
Ecofeminist ethic	Turkish	172	32.69	4.04	1	0.23	83.30	.00
	Turkmenistanian	103	27.90	4.46	273			
Teocentric ethic	Turkish	172	15.56	3.18	1	0.22	79.14	.00
	Turkmenistanian	103	12.11	2.98	273			

Mean scores for environmental ethical attitudes of 172 Turkish and 103 Turkmenistanian students are given in Table 3. ANOVA results showed that there was a significant difference between Turkish and Turkmenistanian students' scores for all four types of ethic approaches [F (1.273) (Anthropocentric)=188.69, $p<.05$; F (1.273)(Ecocentric)=130.54, $p<.05$; F (1.273)(Ecofeminist)=83.30, $p<.05$; F (1.273)(Teocentric)=79.14, $p<.05$)]. Analysis of eta squared values suggested that the effect size of these significant differences were high. According to Green and Salkind, (2004), for eta square values, (.01) means small, (.06) medium, (.14) extensive effect level. Accordingly, it can be said that ethical approaches have a large effect size on Turkish and Turkmenistan students. Table 3 indicates that Turkish students had higher scores than Turkmenistanian students for the "Ecocentric ethic approach" (M=71.34), "Ecofeminist ethic approach" (M=32.69), and "Teocentric ethic approach" (M=15.56). Turkmenistanian students, on the other hand, had higher scores than the Turkish ones for the "Anthropocentric ethic approach" (M=9.92).

NI Levels of Turkish and Turkmenistanian Students

ANOVA and descriptive statistics analyses were conducted in order to test whether there was a significant difference between Turkish and Turkmenistanian students' naturalistic intelligence (NI) levels (Table 4).

Table 4. ANOVA results of the difference between Turkish and Turkmenistanian students' NI levels and descriptives statistics

Group	N	Mean	sd	df	Eta squared(η^2)	F	p
Turkish	172	27.90	7.10	1	0.10	33.02	.00
Turkmenistanian	103	22.89	6.81	273			

The analysis of statistics included in Table 4 indicates that there was a significant difference between NI levels of Turkish and Turkmenistanian students (F (1.273) =33.02, $p<.05$). The eta squared value suggests that the effect size was high ($\eta 2= 0.10$). Additionally, the analysis of the mean scores for both groups of students show that the mean score for Turkish students (M=27.90) was higher than the mean score for Turkmenistanian students (M=22.89). In line with the development levels of the Multiple Intelligence Domains Inventory, Turkish students' mean NI score was considered to be at the "developed" level (24-31) and Turkmenistanian students' mean score was considered to be at the "moderately developed" level (16-23).

Investigation of Differences between Turkish and Turkmenistanian Students' Environmental Ethical Approach (EAA) in terms of the Gender Variable

MANOVA was conducted in order to test whether EEA related gender differences existed between the students' of both countries. EEA scores were treated as the dependent variable and gender as the independent. Normality of distribution and MANOVA assumptions were checked prior to the analysis. Checks including the normality of the data set, Mahalonobis distance of the extreme values, matrix and variance-covariance homogeneity of the data set, and equality of variance suggested that MANOVA can be utilized. The results of MANOVA are presented in Table 5.

Table 5. MANOVA results of the difference between Turkish and Turkmenistanian students' EAA scores in terms of the gender variable

Group	Ethical approach	Gender	N	Mean (X)	p	Partial eta squared	F	Wilks' Lambda
Turkish students	Anthropocentric ethic approach	Female	105	6.52	.006	.043	4.70	.90
		Male	67	5.46				
	Ecocentric ethic approach	Female	105	71.57	.684	.001		
		Male	67	71				
	Ecofeminist ethic approach	Female	105	33.21	.017	.033		
		Male	67	31.67				
	Teocentric ethic approach	Female	105	15.91	.071	.019		
		Male	67	15.01				
Turkmenistanian students	Anthropocentric ethic approach	Female	58	9.91	.954	.000	1.48	.94
		Male	45	9.93				
	Ecocentric ethic approach	Female	58	59.93	.022	.051		
		Male	45	55.28				
	Ecofeminist ethic approach	Female	58	28.31	.296	.011		
		Male	45	27.37				
	Teocentric ethic approach	Female	58	12.24	.632	.002		
		Male	45	11.95				

The results showed that there was a significant different between male and female Turkish students' EAA mean scores [F(4,167)=4.70 p=.00; Wilks' Lambda=.90; partial eta squared=.10]. Bonferroni alpha correction at the value of .013 was utilized when separately analysing each category of ethic approaches, the only significant difference between male and female Turkish students was observed in the anthropocentric ethic approach category (F(1,172)=7.66; p=.006; partial eta squared=.043). Similarly, the analysis of mean scores of female and male Turkish students revealed that the former group had higher levels of anthropocentric ethic approach (M(Female)=6.52; M(male)=5.46).

The analysis of male and female Turkmenistanian students' mean EAA scores, on the other hand, showed that there was not a significant difference between the two (F(4,98)=1.48 p=.21; Wilks' Lambda=.94; partial eta squared=.05). Separate EAA score analyses (based on the .013 alpha correction value) for both groups of Turkmenistanian students within each sub-category of environmental ethic approaches also revealed that there were no significant differences between male and female students (p>.013).

Discussion and Conclusion

In line with the framework investigating the relationship between environmental ethics attitudes (EEA) and naturalistic intelligence (NI), the present study found a high level of relationship between NI and ecocentric and teocentric ethic. In this sense, it can be argued that; participants' NI characteristics have ecocentric and religious roots.

Environmental problems require us to ask questions such as what we value as human beings, what kind of creatures we are, what our place in the nature is, and in what kind of a world we can develop our species (Des Jardins, 2006, p.35). Such questions can also reveal characteristics of individuals who possess naturalistic intelligence. Individuals who have ecocentric ethic attitudes leave their personal benefits aside and act to protect the nature (Dunlap & Van Liere, 1978), and individuals who have teocentric ethic attitudes feel that they need to respect all species in the nature because of the view that they are entrusted to human beings by god (Des Jardins, 2006). There are parallels with such characteristics and the characteristics that individuals with naturalistic intelligence possess; such individuals have developed environmental awareness and want to protect the nature (see for example; Saban, 2005). In this sense, a high level of relationship can be observed between NI and ecocentric and teocentric ethic approaches. As such, the development of NI would positively contribute towards developing ecocentric and teocentric ethic attitudes. Sensitive behaviours towards the environment which is a characteristic of NI have parallels to ecocentric ethic approach. In addition, being sensitive towards plant types, taking care of plants, protecting pets, and having an interest in exploring natural events and species in the nature have parallels with the teocentric approach. In line with the teocentric environmental ethics approach, Des Jardins (2006) stated that human beings –based on their sense of responsibility to the god- respect the creatures created by the god and act responsibly towards the nature that is entrusted to them. The prominent idea in the

ecofeminist environmental ethics approach is that there should be a healthy relationship between human beings and the nature and this relationship can prevent the inequalities between men and women as well as contribute towards achieving equal opportunities. Attention, in particular, is paid to the idea that women are treated unfairly because of the patriarchal way of thinking and this idea forms the basis to destroying the nature (Scarce, 1990; Tamkoç, 1996). Considering the characteristics of NI, it can be observed that a limited number of characteristics of ecofeminism are present in NI. This has reflected itself in ecofeminist ethics in the form of the nature and biotopes where wild life animals live being destroyed in the patriarchal order (Des Jardins, 2006). These ideas include NI characteristics and, at the same time, are in parallel with the ecocentric approach. Evaluation of the societies with which the study is conducted suggests that the ecofeminist approach has not found its place in the society yet. Anthropocentric environmental ethics approach, on the other hand, prioritizes human beings' interests and supports the idea that human beings can dominate the nature as they wish (Dunlap et al., 2000), which is not an observed characteristic of NI. Therefore, it is expected that the relationship between NI and anthropocentric ethics approach would be low and/or negative.

The present study investigated environmental ethic approaches (EEA) and naturalistic intelligence (NI) levels of students from two countries (Turkey and Turkmenistan). The types of environmental ethics investigated in the study included; anthropocentric, ecocentric, ecofeminist, and teocentric ethic approaches. A significant difference between the mean scores of Turkish and Turkmenistanian was observed in all four categories of environmental ethics. It was found that Turkish students' mean scores for the ecocentric, ecofeminist, and teocentric ethical approach categories were higher than Turkmenistanian students' mean scores (See Table 3). Similarly, related research indicated that Turkish students' environmental ethical attitudes and ethical approach levels were high (Karakaya, Avgın & Yılmaz, 2018; Erten & Aydoğdu, 2011). In this sense, the present study can be considered as a guide in terms of investigating various environmental ethic approaches of students from different cultural backgrounds and countries.

From a socio-economic perspective, most of the land in Turkmenistan consists of deserts and there is limited amount of land which is arable. On the other hand, the country has rich sources of petroleum and natural gases and it declared its independence in a relatively recent time, 1991 (Turkish Cooperation and Coordination Agency [TCCA], 1995). In this sense, it is possible to consider that Turkmenistan will adopt pragmatic values in order to join the list as a developed or developing nation and this situation may reflect itself on the education system and affect students. In fact, a university that focuses its tuition on petroleum and natural gases was opened in the country considering its economic benefits (Clement & Kataeva, 2018). Considering those points, it is possible that the "Anthropocentric ethic approach" will be adopted at a higher level in a country which advocated a pragmatic philosophy and needs to develop and grow. When they were part of the Soviet Russia, Turkmenistan citizens were banned from practicing their religion and propagandas aiming to distance people from religion were made (Özbay, 2019). Having been refused to receive religious education for over 70 years might have affected Turkmenistan citizens' approach to religious ethics. The current education system in Turkmenistan does not have any course content regarding the concept of religion. It is possible that this was the reason why Turkmenistanian students' "Teocentric ethic approach" scores were lower than the mean scores of the Turkish students. While the primary school education curriculum in Turkmenistan focuses on "world environment, language development, mathematics, manual skills, fine arts, physical training, singing and music, and fiction", the secondary-high school curriculum focuses on "the principles of scientific knowledge, development of creative abilities, cultural attainment, and physical training" (International Bureau of Education (IBE-UNESCO), 2011). It is understood that the topic of environment receives little attention in the Turkmenistanian education system and this might have resulted in Turkmenistanian students' lower levels of adoption of the "Ecocentric ethic approach".

Environmental problems such as arid lands which result from human activities are the concern of almost all central Asian countries. In this sense, it has a regional essence. The fact that Turkmenistan has set the goal of increasing agricultural production to a level that would be enough for the population of Turkmenistan (Ökmen, 2001) is an indicator of anthropocentric ethic at the level of the government.

Industrial activities near the Caspian Sea where oil fields are located have caused considerable pollution especially in the sea. The waste that was produced was sent to the sea without any treatment. Consequently, many species in the sea were harmed (Ökmen, 2001). Such situations are in line with the anthropocentric ethic approach that reflects human beings' enthusiasm to reign over the nature.

"Religious Culture and Moral Knowledge" course is compulsory in the Turkish education system and is offered from the 4th grade until the end of the 12th grade. Although students are predominantly taught about Islam, information on other religions is included in the curriculum. Both the fact that 90% of the Turkish population

chose Islam and that religion education is provisioned in the Turkish education system may be the reason for why Turkish students' "Teocentric ethic approach" scores were higher than the Turkmenistanian students. Students in Turkey are first introduced to the topic of environment in primary schools as part of Science and Biology courses starting as early as the 3rd grade. The content of these courses include not only general information on the environment but also information and activities on energy transformation, sustainability, environment protection, recycling, biodiversity, environmental problems and finding solutions to those problems (MoNE, 2019). It is possible the reason for why Turkish students' "Ecocentric ethic approach" scores were higher than Turkmenistanian students' scores is the fact that environment related topics are covered extensively in the above mentioned courses. The study conducted with Turkish and Azeri pre-service teachers by Erten and Aydoğdu (2011) found that the former possessed higher levels of "Ecocentric ethic approach" than the latter. The findings of the present study are in line with Erten and Aydoğdu's (2011) findings.

Furthermore, Turkey is playing an active role in international collaborations to find solutions to environmental problems related to most socio-economic issues. Turkey is one of the most successful countries in implementing the Montreal Protocol created in 1991 ("Republic of Turkey Ministry of Foreign Affairs", 2021). In this sense, it can be argued that Turkey has made progress in solving environmental problems and the government prioritizes the ecocentric approach. Becoming aware of environmental problems in Turkey has a history that goes back to the Ottoman Empire era. For example, various precautions were taken to protect water sources in particular during the Ottoman era. Similarly, it can be observed that various practices are employed in different ministries with regards to protecting the environment and non-human species. The above are indicators that a move towards abandoning anthropocentric ethics approach has been initiated. This sensitivity, which can be observed in the political area, has been helpful in developing, extending, and practicing ecocentric ethic attitudes (Ertan, 2004).

The analyses conducted to test gender differences between students from Turkey and Turkmenistan showed that there was not a significant difference between male and female Turkmenistanian students' EAA mean scores. On the other hand, it was found that the anthropocentric ethical approach mean scores of female Turkish students were higher than male Turkish students. The gender differences between the students of both countries are considered to have resulted from the social structure and education system of the countries. This is because education affects the society and the society affects education. Similarly, Erten (2008) attributed the environmental ethic approach differences between teachers in Turkey and teachers in Germany to cultural differences.

Erten's (2008) study conducted with teachers from Turkey and Germany did not find a significant difference between male and female teachers from Germany in terms of ecocentric approach, anthropocentric approach, and antipathetic attitudes towards the environment approaches". On the other hand, there was a significant difference between male and female teachers from Turkey. The present study suggests that female Turkish students have higher levels of pragmatism compared to male Turkish students. However, the fact that the mean scores of female Turkish students in the ecofeminist and ecocentric ethic approach categories were higher than their male counterparts (Table 3) creates a contradiction. It is believed that the source of this outcome can be the modern approaches practiced in the education system and the continuation of the pragmatic and patriarchal way of thinking in the society. Aktaş (2013) underlines traditional views in a "patriarchal" society continue during the process of modernization and those values put pressure on females. Casey and Scott (2006) stated that women and girls adopt a "more affectionate, nourishing, and protecting" role as a result of traditional approaches.

Although there were not significant differences between EAA scores of male and female Turkish students, Turkmenistanian students had lower mean scores than Turkish students in all ethic approaches except the anthropocentric ethic approach (Table 2). This indicates that the Turkmenistanian society is a society that adopts traditional and pragmatic values.

Analysis of Table 5 shows that female Turkish and Turkmenistanian students' mean scores in ethic approaches are generally higher than males. Wongchantra, Boujai, Sata, and Nuangchalerm (2008) utilized the ethics infusion method in order to teach undergraduate students about the environment and environmental ethics. Following the implementation of the method, the results suggested that female participants' knowledge of the environment and environmental ethic levels were higher than their male counterparts. On the other hand, in the study conducted with Australian participants investigating female and male participants' environmental concerns and behaviour within the framework of ecocentric and anthropocentric ethics, Casey and Scott (2006) found that female students' ecocentric environmental ethic scores were higher than the males, and anthropocentric ethic approach scores of the male participants was higher than the females. In their study,

Sungur (2017) found that the gender variable does not cause significant differences in terms of environmental ethics.

Comparison of NI levels of students from both countries suggested that Turkish students' NI levels were "developed" and Turkmenistanian students' NI levels were "moderately developed". The inclusion of the constructivist approach into the Turkish education system allowed students' development of various intelligence domains including the naturalistic intelligence. Multiple intelligences theory is one of the factors that formed the basis of the constructivist approach (Burma, 2003 as cited in Arslan, Orhan, and Kırbaş, 2010). The present study compared both environmental ethic approaches and NI levels of students from two countries. The analysis of related literature indicated that there is only a limited number of studies which investigated intelligence or naturalistic intelligence domains and environmental ethic approaches. Future studies can be conducted to investigate the effects of multiple intelligence domains on environmental ethic approaches.

This finding was, in fact, also supported in the results calculated in Table 3. Turkish students' mean "Ecocentric ethic approach" score was high. According to Erten and Aydoğdu (2011) those who possess ecocentric ethic approach protect the environment without thinking about their personal interests, they consider all living creatures as a part of the nature and advocate that the nature should be protected as a whole. Similarly, individuals whose NI is developed possess characteristics such as being sensitive of bio-diversity, establishing contact with living creatures, protecting them, being sensitive of the nature, feeling the nature, and recognizing and categorizing living creatures (Lazear, 2000). Therefore, it can be argued that those who possess ecocentric ethic approach also have a developed NI. In their study, Okur, Yalçın-Özdilek and Sezer (2012) found that an individual's attitude towards the environment is a significant predictor of their NI levels. This was also confirmed in another study conducted by Yenice, Özden and Alpak Tunç (2016). It is a known fact that cultural constructs affect intelligence domains. As such, Gardner (2004) underlined that intelligence domains develop in different ways in different cultures. In line with this, the positive effect of the constructivist approach that has been in practice in Turkey since 2004 (which prioritizes individual differences and avoids rote learning) should be emphasized.

Turkmenistanian students had moderately developed NI. It is possible that multiple intelligences theory and the qualities that are expected to develop for the NI are not well integrated into the environment related courses. Therefore, it is possible to argue that those students did not have enough opportunities to develop an environmental ethic approach or their NI. In addition, for many years Turkmenistan followed monoculture in agriculture that is to say; only cotton was harvested for many years, and –as a result- the land became arid. Therefore, unavoidably, the environment was harmed. This situation which indicates that agriculture technique and culture did not develop (Ökmen, 2001) is, at the same time, an indicator that individuals did not sufficiently develop naturalistic intelligence.

Awareness and understanding of environmental ethic approaches are crucial for protecting the nature and prevent environmental disruptions. Among environmental ethic approaches, the ecocentric approach is considered to have more long-lasting effects in the solution of environmental problems. According to Erten and Aydoğdu (2011), "individuals -who believe that the nature should be protected for the sake of the nature- can be expected to demonstrate behaviours that are beneficial to the environment" (p. 165/6). In this sense, if we are to find solutions to environmental problems, it is important to ensure that environmental ethics related courses are included in the curriculums of every country and ecocentric-oriented teaching activities are practiced.

Suggestions

In the curriculum of both countries, there may be educational activities that contribute to increasing the environmental-centered ethical understanding together with activities that support the fields of naturalist intelligence.

It is recommended to inform students at schools and universities about the eco-centered ethical approach, which is effective in minimizing environmental problems. This knowledge should not only remain at the theoretical level, but should also be seen in behavior.

It is important that environment-centered ethics take place in programs as a discipline given with student-centered approaches.

It is recommended to investigate the effects of multiple intelligences theory on ethical approaches to the environment as a basis for future studies.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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Scientific Studies on Climate Change, Children and Education: Current Situation and Suggestions

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Abstract

Climate change is at the top of the world's agenda due to the major problems it creates. It is a subject that concerns all humanity and living things with its many different dimensions, from economy to social life. However, it is children who are most affected by the problems arising from climate change and will be affected in the future. Within this scope, the aim of this study is to examine the effects of climate change on children through the current literature and to interpret the studies on this subject in Turkey. The research was conducted in a qualitative way and content analysis method was used. The content of the study was limited to researches focusing individuals aged 0-12, including early and late childhood. National studies in Turkey on climate change for children and their education are included in the scope. According to the results, there has been a noticeable increase in studies on the effects of climate change on children and their education, especially in the last five years. Furthermore, most of the studies focus on examining dimensions such as knowledge, awareness, perception and attitude. However, there is a great need at the moment to teach children, who are the architects of the future, permanent environmentally and eco-friendly behaviors.

Introduction

Due to the consequences of climate change, it has been one of the problems that humanity has experienced the most throughout history (Hosking et al., 2011). As many knows, massive changes have occurred in the lives of people who have had to deal with these climate change sourcing problems; many people have been displaced from their homes worldwide and some parents even stated that they are worried about the future of their children (Akachi et al., 2009; McMichael, 2014). These concerns of parents can be understandable because by the end of this century, our planet is predicted to will have warmed by an average of 2 degrees Celsius with human activities (Hellden et al., 2021). Children have contributed the least to the climate crisis but will pay the highest price. Children are undoubtedly the most affected by these problems; because they are not sufficiently ready for the extraordinary consequences of climate change, as they have not yet reached a sufficient level in terms of mental and physical development (Shea, 2007; Urbano et al., 2010). Therefore, children have to bear the burden of climate change. The negative consequences of climate change are a danger that awaits children even before they are born, because the child is fed with whatever the mother feeds while in the womb. The nutrition of the mother also depends on the climatic conditions (Pacheco, 2020). Children are more sensitive to the consequences of climate change, as they have not yet developed enough for themselves and are dependent on others (Currie & Deschenes, 2016; Kousky, 2016).

The effects of climate disasters that the child is exposed to before birth have also been proven in neurodevelopmental disorders in childhood (Perera, 2017). Among the climate problems that affect children are the carbon emissions caused by fossil fuels and the effect of greenhouse gases. These can cause dangers such as lung diseases, developmental disorders, low birth weight, childhood asthma and increased cancer risk in children. Furthermore, children are the ones who will feel the deadliest effects of rising temperatures, drought, water scarcity and air pollution. Children's need for water is much more than adults and need more water than adults, which they need to consume per weight. The scarcity of water prevents some agricultural products from growing. This leads to a decrease in meat consumption due to the nutrition of animals, which leads to the inability of children to receive the necessary amount and quality of nutrients for their development (Godfray et. al., 2018). 438,000 people died in 2015 alone from diseases such as poor water quality, malaria, diarrhea, cholera, dengue fever and meningitis, and two-thirds of these are children under 5 years old (UNICEF, 2013; UNICEF, 2015). Scarcity of water also causes people to migrate. When people migrate from where there is no water, it is girls who are more affected. In unsafe conditions, girls are given the task of traveling long distances

to bring water to the house. In the event of a possible disaster, girls are the first to leave the schools. It seems that in the coming years, bigger threats await their children than they do now.

Although it is known that climate change affects every person, it also has some other significant effects on children. It has been stated that, depending on the consequences it creates, especially after extraordinary climatic events and natural disasters, depression, stress, phobia, sleep disorders, attachment disorders, anxiety and even substance addiction can be seen in children, especially post-traumatic stress disorder (Burke et al., 2018). Among the climate problems that affect children are the carbon emissions caused by fossil fuels and the effect of greenhouse gases. These can cause dangers such as lung diseases, developmental disorders, low birth weight, childhood asthma and increased cancer risk in children (Xu et al., 2012). Reducing the effect of greenhouse gases alone means saving the lives of millions of children.

Another dimension of climate change that can be evaluated for children is its connection with children's rights. Although the 'Convention on the Rights of the Child' does not specifically mention the issue of climate change, it contains provisions regarding the need to protect children from the harmful effects of environmental pollution. The rights of children who have become refugees as a result of migration due to climate change have been emphasized (Arts, 2019).

Table 1. Articles related with global climate change in the "International Convention on the Rights of the Child"

Article No	Rights of the children related with climate change
Article 3:	Children's needs must be the top priority. Climate change studies should be focused on countries that are more vulnerable in this regard.
Article 6:	Children have the right to survive and develop. Disasters such as drought, epidemic, flood and hunger directly threaten the lives of children.
Article 9-10:	Children have the right not to leave their parents against their will. As a result of climate change, millions of children are forced to leave their places of residence and may even go out of the country.
Article 12:	Children have the right to have a say. The issue of climate change is an issue that affects children and children should be able to have a say in this matter.
Article 24:	Children have the right to benefit from health services. Situations caused by climate change may prevent children from benefiting from health services.
Article 27:	Children have the right to live with an adequate standard of living. Situations related to climate change can affect children's living standards.
Article 28:	Children have the right to receive education. Children may have to postpone or drop out of school due to natural disasters.
Articles 19, 32 and 34–36:	Children have the right to be emancipated from all forms of violence and exploitation. Children and their families can be away from their homes when disasters due to climate change occur. This can lead to child abduction and human trafficking.
Article 30:	Children have the right to an indigenous culture and language. Climate change threatens ecosystems with close ties to indigenous culture.
Article 31:	Children have the right to create and play. As disasters related to climate change threaten the child's environment (school, home…etc), children may stay away from recreation and play activities.

(All of the provisions and the specific interpretations of the provisions belong to the International Convention on the Rights of the Child and are quoted from the "UNICEF 2021 - The climate crisis is a child rights crisis: Introducing the Children's Climate risk index" report)

As highlighted by many nations at 26th United Nations Climate Change Conference of the Parties (COP26), in Glasgow, and by IPCC reports, reducing the effect of greenhouse gases alone means saving the lives of millions of children. One billion children are at 'extremely high risk' from the impacts of climate change, according to a Southampton-led consortium of researchers who conducted the analysis for a key UNICEF report that was presented at the UN Climate Change Conference, COP26. Entitled "The Climate Crisis Is a Child Rights Crisis: Introducing the Children's Climate Risk Index (CCRI)", the report presents the first comprehensive worldwide analysis of climate risk to children (UNICEF, 201). It combines different types of information – physical data, such as floods and droughts, with social data, such as access to essential services – on a single map to show governments across the globe where they most need to focus their resources to protect vulnerable children. In addition, climate change produces hotter temperatures and worse air pollution—and that matters to a child's brain. Some studies conducted by Harvard University, have shown that heat and air pollution can influence

everything from how a brain develops to how well a student does on a test. Many research studies have suggested that the more particulate matter a child or teen breathes, the more their brain may be harmed (Harvard T. H. Chan School of Public Health, 2021).

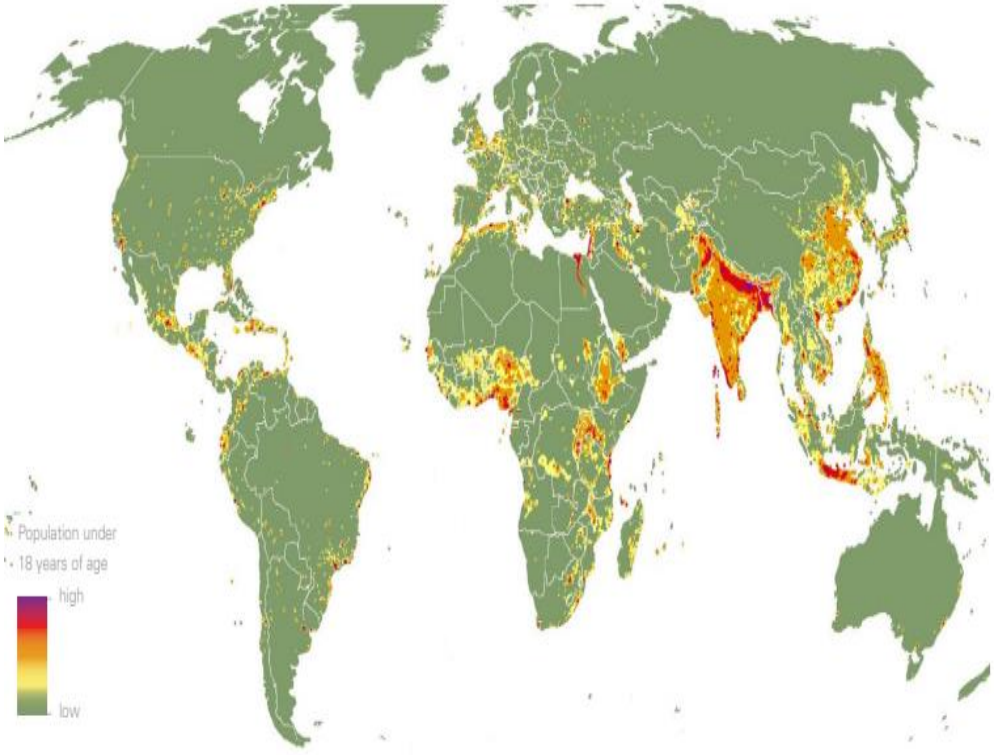
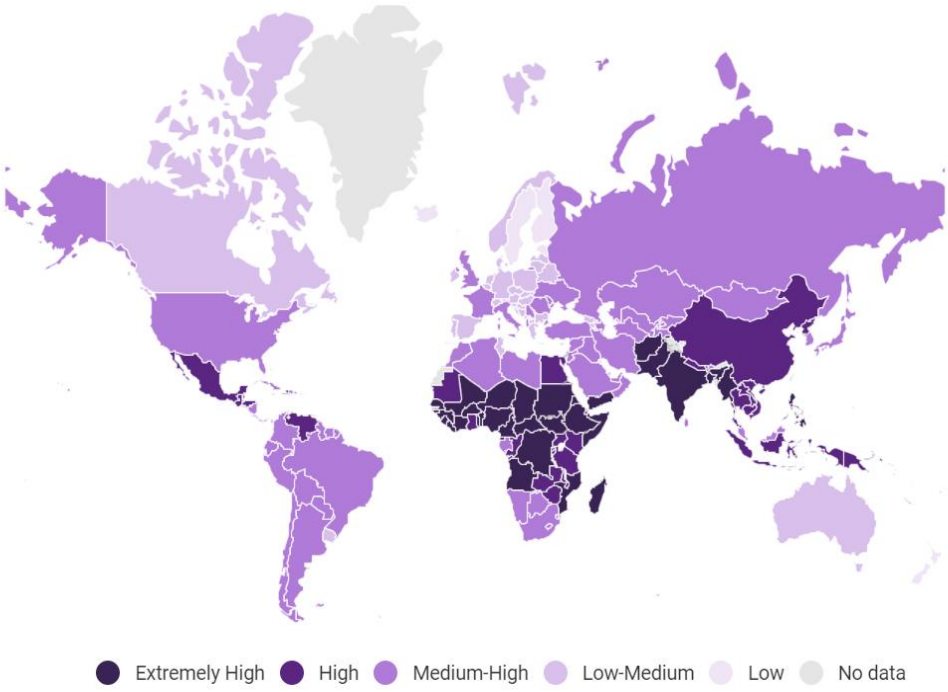


Figure 1. Distribution showing the risk of child and young population being affected by climate change-related disasters (UNICEF, 2015)



Note: Approximately 1 billion children (nearly half of the world's children) live in extremely high-risk countries

Figure 2. Children's climate risk index atlas (UNICEF, 2021; https://data.unicef.org/resources/childrens-climate-risk-index-report/)

"What we found surprised us. The scale of exposure is even larger than we anticipated: there are very few children in the world who are not exposed to some form of hazard – for example floods or heatwaves – resulting from climate change," says Hutton (2021) who led and conceptualized the risk mapping approach. From the difference between both maps above, it can be seen that how much the situation has changed in just five years. Also, one billion children are at 'extremely high risk' from the impacts of climate change, according to a Southampton-led consortium of researchers who conducted the analysis for a key UNICEF report that was presented at the 26th UN Climate Change Conference (COP26). Considering all these effects of the climate crisis on children, almost every country should focus on deeper and faster studies on this issue. Turkey is among the countries that have been affected by the climate crisis in recent years. Flood disasters in many parts of the country, widespread fires, catastrophic weather events that threaten the habitat of many living species make the measures to be taken in this regard very essential. Undoubtedly, children, who will be adults of the future, will be the individuals most affected by the above-mentioned effects today and tomorrow. At this point, the climate studies carried out in the children's center in Turkey and their quality should be increased and shaped according to the needs. For this reason, in this study, firstly, general trends and analyzes of existing studies were desired. Within the scope of these effects mentioned above, the aim of this study is to examine the effects of climate change on children through the current literature and to interpret the studies on this subject in Turkey. The content of the study was limited to individuals aged 0-12, including early and late childhood. National studies in Turkey on climate change for children and their education are included in the scope.

Method

The research was conducted in a qualitative way and content analysis method was used. This research, involves purposeful use for describing, explaining, and interpreting collected data (Creswell, 2013). Leedy and Ormrod (2001; p. 155) define this method as "a detailed and systematic examination of the contents of a particular body of materials for the purpose of identifying patterns, themes, or biases". In line with the purpose of the study, all scientific studies and government-supported scientific projects in the field of education on children and climate change in Turkey were included in the center. The study aims to describe the biometrical characteristics of the theses, articles and scientific project reports published in educational journals reached through using "environmental education, climate change, children" keywords. The aims, target age groups, methods, results and general tendencies of these studies were tried to be examined in depth. The following steps were carried out in the study, respectively: (1) Examination of the effects of climate change on children according to the common literature and current scientific researches; (2) Examination of higher education-specific programs, research centers and schools in the field of climate change and its effects in the education system in Turkey; (3) Determining the scope and criteria to be included in the research; (4) Determination of scientific studies and projects covering the early childhood and primary education period on climate change in Turkey and examining their contents; (5) Analyzing and interpreting research data obtained in the context of children and climate change in Turkey; (6) Developing further recommendations for educators, practitioners and researchers in terms of studying global climate change and child as a result of the findings obtained.

The credibility of the results is considered one of the most important criteria of scientific research. Patton (2002) states that validity and reliability are two factors which any qualitative researcher should be concerned about while designing a study, analyzing results and judging the quality of the study. In this respect, validity and reliability are the two most commonly used criteria in research. Errors such as handling inadequate results, themes based on closed answers, misinterpreting data can jeopardize the credibility of the qualitative study. Asking people who have general knowledge about the research subject and specialized in qualitative research methods to examine the research from various dimensions is another measure that can be taken in terms of credibility (Creswell, 2003). In this study, peer debriefing was preferred in order to make realistic and reliable analyzes on the obtained documents. In this review, two other experts took a critical look at the processes from the research design to the collected data, their analysis, and the writing of the results, and provided feedback to the researcher.

Sampling and Limitations

The data for the study consisted of the theses, articles and scientific reports reached through Council of Higher Education Thesis Center, Science Citation Index (SCI), Social Science Citation Index (SSCI) and Art & Humanities Citation Index (A&HCI) international citation indexes, Scopus and Ulakbim TR Dizin database published between 1988 and 2021 using "environmental education, climate change, children" keywords. As a result of the initial scanning, 1988 is considered to be the starting date for this line of research since the first

article on the subject matter was found to be published in. It should be noted that the sampling of the study has some limitations. Firstly, the sample did not involve of all the publications on environmental education in the related literature. The study is limited to the issue of climate change, which is included in environmental education research. Additionally, the scope of the study is limited to related published work only in thesis and research article format and does not cover conference papers, reviews, editorials, notes, letters, short surveys, book chapters and books published on the topic. In addition, year of publication was also set to be another limitation for the reasons mentioned earlier. There was no limitation regarding the publication language, and thus, articles published in any language were included in the analyses. Finally, it should be stated that this study is limited to the studies conducted in the center for 0-12 age group children and carried out in Turkey.

Data Collection

Since 1988, 138 topics have been researched as theses in the field of environmental education in the last 30 years in our country (see Graph 1); eleven studies of them are directly on climate change and especially seven of them are focused on children. As a result of the scanning conducted; 7 theses, 5 research articles and 5 government-coordinates project reports publications in total were reached for this time period from past to present year. For the aim of the study, search limitations such as publication type (i.e., journal article) and time period were set. The analyses results for this sample of 19 studies revealed the findings related to the annual distributions of the articles.

Data Analysis

In order to carry out content analysis, firstly determined researches (graduate theses and research articles and government-supported projects conducted by Ministry of Environment, Urbanization and Climate Change) were listed. The basic information of each study was coded and the variables to be included in the study were tried to be determined. At the end of the preliminary examination, each study examined in this research was divided into subgroups of "Aims", "Research Methods", "Research Duration", "Study Groups", "Subject Areas", "Study Types" and "Results", separated and analyzed. The data obtained as a result of the analyzes are presented in tables and graphics.

Results

The findings and comments obtained from the studies are examined in this section. The obtained data are presented to the reader under the determined sub-headings (purpose, research types, research method, research durations, study groups, subject areas, results) in tables and graphics. Themes, codes and frequency values of the related analysis are given in the tables and graphics.

First of all, it should be said that Turkey has taken a supportive stance and participated internationally in the search for solutions since the years when environmental problems emerged on the world agenda (see Figure 3). When we turn our focus to the educational situation on this subject, we encounter the following findings. In Turkey, great importance has been given to environmental education for nearly 30 years. Many dimensions related to the environment, from pre-school to higher education, have been included and implemented in national educational programs. Looking at higher education, ‘Environmental Education’ course was made compulsory in classroom teaching since 2007 and in early childhood teacher training undergraduate programs in 2018 (Council of Higher Education, 2018). These programs cover the training processes for the prevention of the climate crisis more than in the past. Additionally, the trend of awareness, which has been developing and increasing in the last 5 years, stands out in the context of climate change. Since 1988, 138 topics have been researched as theses in the field of environmental education in the last 30 years in our country (see Graph 1). Eleven studies of them are directly on climate change.

It is seen in the graph that scientific research on environmental education has been condensed since 2000. The first study directly on climate change and children's education was conducted in 2013 and the number has increased until this year. A large number of scientific studies have been identified on this subject. It is noteworthy that researches have intensified especially in the last 20 years. There has been a noticeable increase in studies on the effects of climate change on children and their education, especially in the last 5 years. This situation is thought to be caused by a result of the reflection of the climate crisis and environmental problems in our daily life.

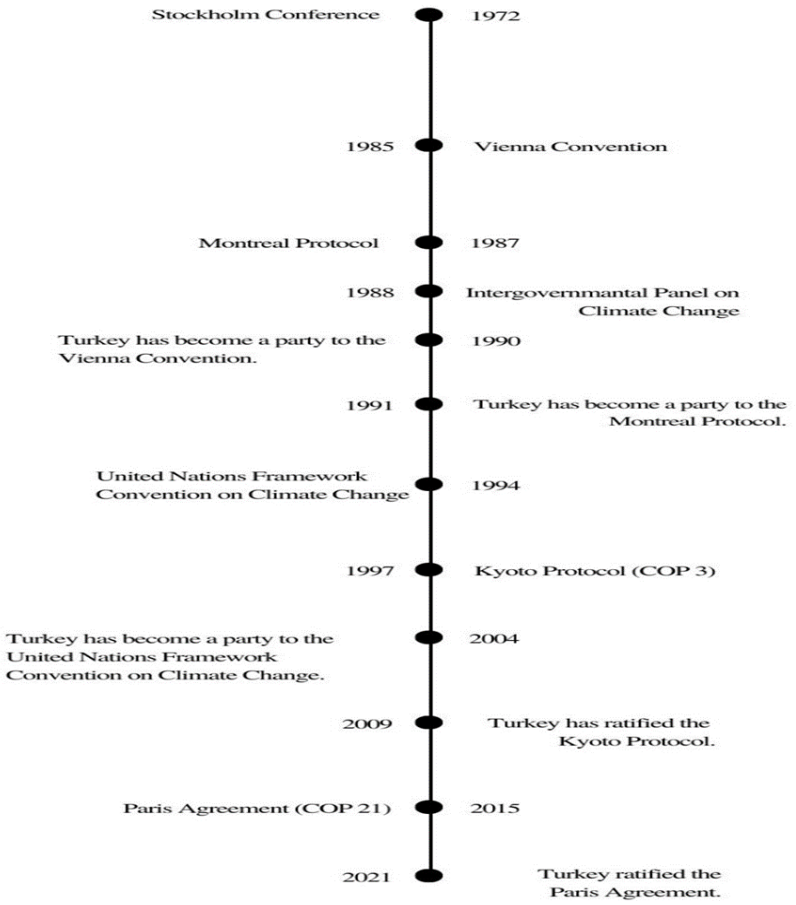
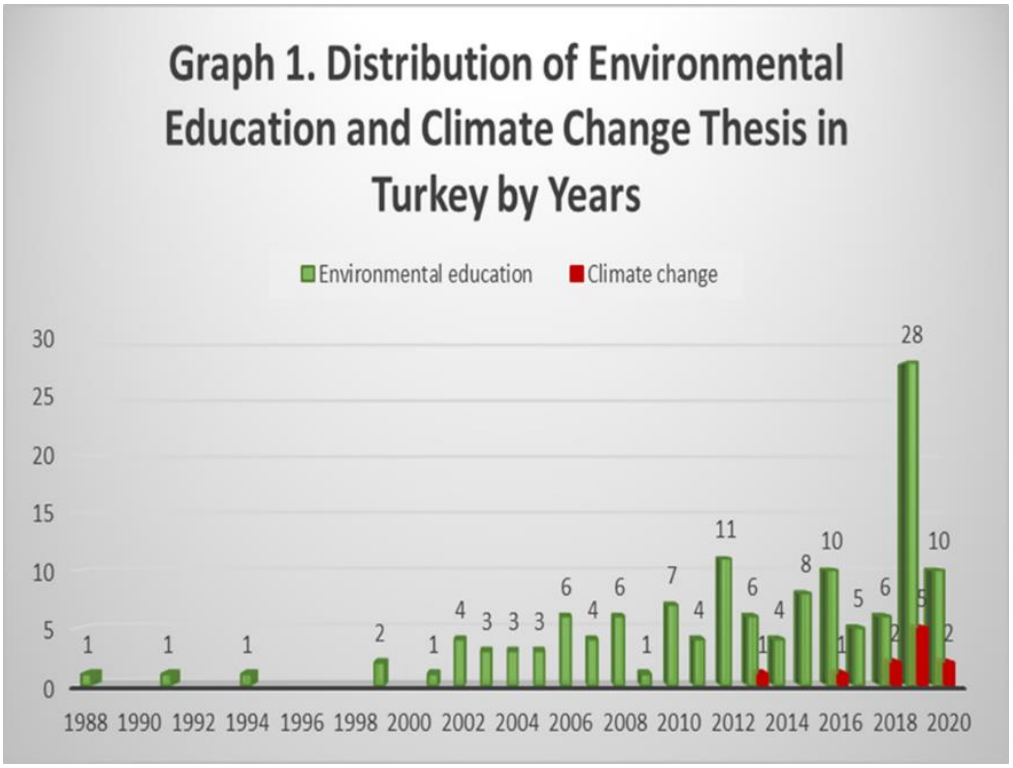


Figure 3. Timeline of Turkey's international participation



Graph 1. Distribution of environmental education and climate change thesis in Turkey by years

Table 2**.** Research articles published about global climate change and children in Turkey

Year	Author/s	Journal	Theme	Sub-Theme	Sample/ Study group	Results
2012	Article 1 (A1)	Erciyes Medical Journal	Climate change	Effects of Climate Change on Child Health	Document analysis	It has been determined that climate change has physical and mental effects on children.
2017	Article 2 (A2)	Anatolian Journal of Teacher	Light pollution	Students' Perceptions of Light Pollution	Children age of 11	Bird species and sea turtles, whose populations are decreasing due to light pollution, attract the attention of students.
2019	Article 3 (A3)	Baskent University Journal of Education	Environmental Problems	Investigation of Secondary School Students' Cognitive Structures for Environmental Problems Through Drawings	Children age of 12	Environmental problems are caused by humans. Students do not have knowledge about the concepts of global warming, greenhouse effect and acid rain .
2019	Article 4 (A4)	International Primary Education Research Journal	Unconscious Consumption of Natural Resources and Environmental Problems	Determining the Readiness Levels of 6th Grade Students about Unconscious Consumption of Natural Resources and Environmental Problems with Cartoons	Children age of 12	Children understood the visual messages about environmental problems given in the cartoon, but they could not diversify the solutions.
2020	Article 5 (A5)	Journal of Geography	Climate Change Education	Comparison of Secondary School Curriculums in the World and in Turkey According to Climate Change Education Approach	Document analysis	The principle of integrating climate change with local elements, which is one of the components of climate change education, is given superficially in our country's curriculum.

As seen in Table 2 and Table 3, there are more researches at the primary school level. It can be argued that there is a greater need for educational content research on early childhood period. Most of the studies focus on examining dimensions such as knowledge, awareness, perception and attitude (see Figure 4). However, there is a great need at the moment to teach children, who are the architects of the future, permanent environmentally and eco-friendly behaviors. A cleaner future can be talked about when knowledge and values turn into behavior.

Another source of data on climate change and children's education is government-supported projects. The studies carried out within the scope of this subject by the Ministry of Environment, Urbanism and Climate Change have been examined. Comprehensive projects covering various themes of environment, sustainability and climate change were encountered. Also, it is seen that mixed methods are used in government-supported projects and individuals from different age groups (children, teachers, parents, etc.) are included in the process. Therefore, the wider segment of society is involved in the process.

Table 3. National masters and doctoral theses on global climate change and children in Turkey

Year	Author	Institution/ organization	Theme	Sub-Theme	Sample/ Study group	Results
2018	Theses 1 (T1)	Ankara University	Climate Change	Climate Change in Social Studies Curriculum and Textbooks	Children age of 10-11-12-13	The reflection level of most of the achievements determined for the relationship between climate, human and environment in the textbooks was found sufficient.
2019	Theses 2 (T2)	Kastamonu University	Climate Change	The Effect of the Climate Change Program Applied to Five-Year-Old Children on Children's Views on the Concept of Climate Change	Children age of 5	It has been observed that the climate change program applied to 5-year-old children has an effect on children's views on the concept of climate change.
2019	Theses 3 (T3)	Aksaray University	Global warming	Investigation of Secondary School Students' Knowledge and Perceptions of Global Warming	Children age of 11-12-13	It has been observed that the students have an average level of knowledge about global warming, the global warming knowledge level of the students studying in the 5th grade is significantly higher than the students at the other level, and the out-of-school learning environment has an effect on the students.
2019	Theses 4 (T4)	Adnan Menderes University	Environmental Education	Investigation of Children's Books in Eco-Schools in terms of Environmental Education	Children age of 0-6	It has been determined that the books do not include the theme of climate change at all.
2019	Theses 5 (T5)	Hacettepe University	Environmental Education, Climate Change	Investigation of Primary Education Programs in terms of Sustainable Development Goals, Environmental Education and Climate Change	Children age of 7-8-9-10-11-12-13-14	Some of the achievements of the compulsory courses Life Science, Science, Social Studies, History of Revolution and Kemalism are suitable for some goals.
2020	Theses 6 (T6)	Erzincan Binali Yildirim University	Global warming	6th Grade Students' Metaphors and Metaphorical Perceptions on Global Warming	Children age of 12	It has been determined that the students are aware that everyone should fulfill their duties and make an effort to solve the problem of global warming, which has become a danger for living things and the world.

2020	Theses 7 (T7)	İstanbul University	Climate Change	Examining Climate Change Education in the World and in Turkey and Suggesting an Education Model	Children age of 12	It has been determined that the learning-teaching strategies chosen in accordance with the climate change education approach and the teaching materials prepared accordingly give positive results in correcting the misconceptions about climate issues.

Table 4. Government-coordinated projects (by MOEUCC) in the context of global climate change and children in Turkey (Republic of Turkey Ministry of Environment Urbanization and Climate Change, 2021)

Project name	Target group	Theme	Sub-Theme	Purpose of Project
Development of Awareness Project on Climate Change	Starting from kindergarten and preschool, students at all levels, preservice teachers, teachers, local governments	Global climate change	---	Increasing the awareness of students, teachers and local governments about climate change.
The Voice of Meteorology	Primary and secondary school students	Environment	Climate, climate change, meteorology, meteorological disasters, renewable energy systems	The aim is to raise awareness with Meteor FM radio broadcasts on environmental issues such as climate, climate change, meteorology, meteorological disasters, and renewable energy systems.
Family Education Program	Parents	Education	Global warming, greenhouse effect, communication, law, economy, health, media, energy saving	The aim is parent education on global warming, greenhouse effect, communication, law, economy, health, media, energy saving.
Water Ambassadors	Preschool, Primary, Secondary and Higher Education students, teachers, parents	Water use	Environmental protection, sustainability, climate change	The aim is to increase the level of knowledge about the use of water resources, to protect the environment and to differentiate usage habits.
Energy Child Project	primary school students	Energy efficiency	Global warming	The aim is to teach children the use of energy.

Conclusion

Climate change is at the top of the world's agenda due to the major problems it creates. There is clear evidence that it will exacerbate the underlying social, economic and ecological factors that cause global illness and death for all age groups (Watts et al., 2018). It is a subject that concerns all humanity and living things with its many different dimensions, from economy to social life. However, it is children who are most affected by the problems arising from climate change and will be affected in the future. The natural and environmental disasters that have been experienced for especially two years, inform us how quickly we need to move this issue to the center of our lives. At the end of COP26, we can discuss for hours here the issues on which countries have agreed and agreed. However, one important the dimension to emphasize is our “future”, that is, “our children and youth”. Increased poverty from climate change could directly harm a child's mental wellbeing, with particularly detrimental effects if natural disasters also increase (Hanna & Oliva, 2016). Sanson and Burke (2020) also state climate change as an urgent issue of structural violence and intergenerational justice that demands attention from psychologists, scholars, practitioners, activists and policy-makers, with particular emphasis on the needs of current and future generations of children.

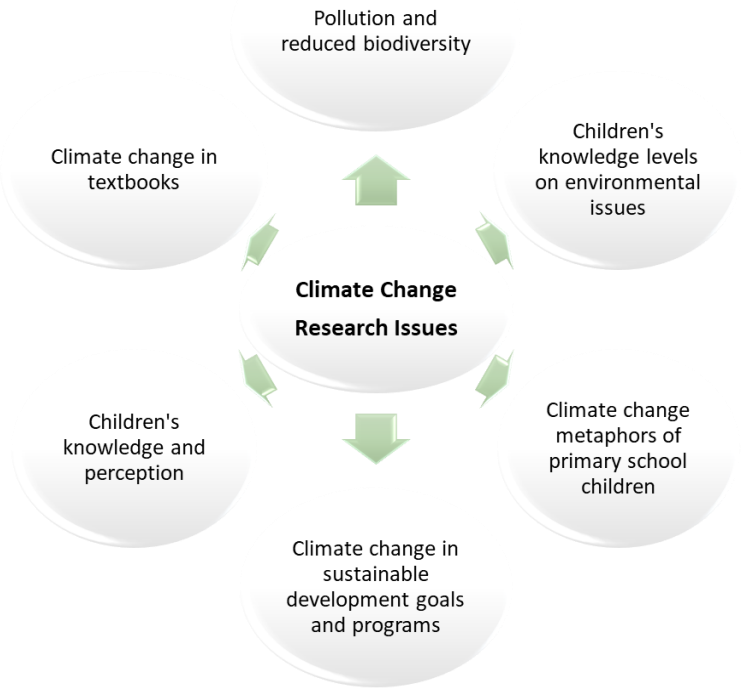


Figure 4. Research topics of scientific studies on climate change and children in Turkey

As being adults of today, although we take urgent precautions, it will be possible to overcome the problems and get long term results only with the education of our children. Focusing on children also helps us to see the injustice and urgency of addressing climate change and encouraging the current adult generation to recognize its responsibilities and "moral duty" (Cripps, 2017) to ensure that today's children and their descendants will have the basic conditions for flourishing (Sanson & Burke, 2020). I thought that in order to be able to decide better what we can do about this issue; we should first look at "how Turkey is" in this regard. For this purpose, it is examined that the current scientific researches on education and projects carried out by the ministry on climate change in our country. Thence, the aim of this study is to examine the effects of climate change on children through the current literature and to interpret the studies on this subject in Turkey. This purpose coincides with the implication of Currie and Deschenes (2016). They imply and emphasized that in states, cities, and communities all over the world must promote preparedness and resilience for the effects of climate change especially for children.

When the scientific studies reached are examined, it is clearly evident that environmental education has been given great importance for many years in Turkey. When it comes to the education of children, environmental education has been made compulsory in pre-school and primary school education programs and teacher training programs in the last 10 years (Council of Higher Education, 2018). These programs cover the training processes for the prevention of the climate crisis more than in the past. A large number of scientific studies have been identified on this subject. It is noteworthy that researches have intensified especially in the last 20 years (see Graph 1). There has been a noticeable increase in studies on the effects of climate change on children and their education, especially in the last 5 years. This situation is a result of the reflection of the climate crisis and environmental problems in daily life. Another result obtained, there are more researches at the primary school level. In addition to these, it appears to be that there is a greater need for educational content research on early childhood period.

According to another result, most of the studies focus on examining dimensions such as knowledge, awareness, perception and attitude. However, it is thought that there is requirement for applied and more educational studies to teach children, who are the architects of the future, for further permanent environmentally and eco-friendly behaviors. A cleaner future can be talked about when knowledge and values turn into behavior. It is seen that mixed methods are used in government-supported projects and individuals from different age groups (children, teachers, parents, etc.) are included in the process. Therefore, the wider segment of society is involved in the process.

Recommendations for Further Research and Policy

As a result of the results obtained in this study, many suggestions come to the fore on climate change, children and their education. In this regard, both researchers and educators and government units have crucial roles. The following recommendations are presented in order:

In solutions, it is necessary to prioritize the most vulnerable segments, the first of which is children. Children should be provided with climate education and nature skills that are critical to adapting to and preparing for the impacts of climate change. By developing qualified education programs, children should be able to interact more with the environment; thus, they should be supported to develop ecocentric attitudes**.** Moreover, children's ideas on climate change should be listened to and action should be taken. Within the scope of this purpose, theoretical and practical educations that will raise environmental and climate awareness for children should be increased. Country governments should reduce the existing inequalities (especially in financial terms) regarding the climate among their children. While making future plans for climate change, investments for children should also be planned. Climate adaptation and resilience investments should be increased in basic services for children. It is recommended that as much as possible, everyone should be involved in this process**.**

At the higher education level, some other suggestions have been considered in the dimension of climate change, children and their education in the country. In fact, these can be an action plan for Turkey. First off, climate change departments and research centers should be established in more universities across the country. In this country, there are very few academic programs directly on climate change and education. There is a necessity to establish departments, institutes and even schools in the field of sustainability and climate change. In addition, a consortium should be offered students opportunities to become well versed in the interconnected challenges of climate change. Must courses on climate change and its effects in teacher training programs. It is strongly recommended that more detailed and diversified mandatory or elective courses should be added to the teacher training programs who will give this education to our children. Hence, there is a need to carry out more scientific researches. Academics, researchers and scientists working in different faculties and working on different disciplines should do more scientific research on the climate crisis, education and children. There should be an increase in the theses produced on this subject.

Another suggestion is that children and young people should be empowered to be agents of change. Children's ideas on climate change should be listened to and action should be taken. Theoretical and practical educations that will raise environmental and climate awareness for children should be increased. By developing qualified education programs, children should be able to interact more with the environment; thus, they should be supported to develop ecocentric attitudes. Children should be provided with climate education and nature skills that are critical to adapting to and preparing for the impacts of climate change.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the author.

Acknowledgements or Notes

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The Role of Microteaching on Pre-Service Primary School Science Teachers' Conceptual Understandings Regarding Phases of the Moon

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Abstract

Microteaching is a significant way to prepare pre-service teachers to overcome specific challenges in a natural classroom environment. It is widely accepted that pre-service science teachers gain pedagogical benefits from microteaching activities. Furthermore, microteaching enhances the conceptual understanding of the presenter on the related teaching topics. This research intends to map two pre-service science teachers' conceptual understanding before and after engaging in microteaching on the concept of phases of the moon. The data were collected through pre and post-interviews and observations of microteaching. Activated knowledge elements during interviews and microteaching were determined and compared. The study's results provided evidence that microteaching is a fruitful way to improve pre-service science teachers' understanding of phases of the moon. Furthermore, it was detected that both the quality and quantity of pre-service science teachers' knowledge elements increased after their microteaching engagements

Introduction

Astronomy concepts have been regarded among the most significant agents in teaching the basics of science since it includes apprehensible laws (Schatzman, 1972) and themes, facts, and paradoxes that easily fascinate students (Lelliott & Rollnick, 2010). Therefore, teaching astronomy concepts (e.g., gravity, the night-day cycle, the seasons, and phases of the moon) has taken an important place in various levels of formal education and informal education, such as museums and planetariums. In astronomy education, moon-oriented research studies have focused on moon phases, eclipses, and tides since these were perceived as difficult to conceptualize. These difficulties emerged from the complex nature of the sun/moon/earth system (Gazit et al., 2005) and shortcomings in teacher education programs regarding astronomy (Hemenway, 2009). In addition to these barriers, an individual's lack of spatial abilities also hinders the development of a sophisticated understanding of moon-related issues (Black, 2005; Cole et al., 2015; Wilhelm, 2009). Moon-related topics require performing different types of spatial abilities. Geometric spatial ability is needed to visualize the dimensions of celestial bodies, and spatial projection ability is required to visualize celestial bodies considering the location of an observer (Wilhelm et al., 2013). Furthermore, spatial transformation ability is needed to understand the different appearances of celestial bodies from the earth and space perspectives (Plummer, 2014). Correspondingly, research studies reported that individuals with better performance on spatial ability tasks explained phases of the moon more accurately (Wellner, 1995). Despite the complexity of the topics regarding the moon, it requires teachers to have a solid understanding of the phases of the moon topic. Unsurprisingly, the studies showed that teachers' misconceptions limit their students' learning (Monk, 1994). In this aspect, pre-service teachers should acquire a sophisticated understanding to meet their future teaching responsibilities and competencies. However, an immense body of research (Kanli, 2014; Schoon, 1995; Trundle et al., 2002; Türk et al., 2017) reported deficiencies in pre-service teachers' conceptual understandings pertinent to phases of the moon topics.

Misconceptions of pre-service teachers hinder the development of a sound understanding of moon's phases topic (Schoon, 1995). Therefore, explicit attention has been paid to the literature to explore teaching methods and techniques to improve pre-service teachers' conceptual understandings regarding the phases of the moon. Student-centered activities following an inquiry-based teaching approach providing students with a wide range of learning opportunities, such as observation of the moon for an extended period, discussion on the pattern of the moon,

modeling or explaining the sun/moon/earth system, are effective in improving pre-service science teachers' understandings (Abell et al., 2002; Düşkün & Ünal, 2020; Ogan-Bekiroglu, 2007; Trundle et al., 2002, 2006). Furthermore, studies showed that technology-enriched inquiry activities, such as examining the change in the moon's appearance via software and designing animations related to moon phases, also fostered pre-service teachers' understanding (Bell & Trundle, 2008; Nielsen & Hoban, 2015).

As indicated by the relevant literature in astronomy education, student-centered teaching approaches constructed on discussion, developing models, natural observations, and technological equipment usage stimulates pre-service teachers' conceptual understanding of moon-related topics. However, at this point, it should be noted that implementations based on these teaching techniques take extensive periods and needs expensive technical devices or software. For instance, the research of Abell et al. (2002) covered observation, keeping records, and group discussions lasting six weeks. Likewise, Ogan-Bekiroglu, (2007) researched pre-service teachers' understanding of lunar phenomena. Fourteen weeks were devoted to model teaching and learning activities in the research. On the other hand, creating digital teaching sources (Nielsen & Hoban, 2015) or using planetarium software (Bell & Trundle, 2008) is highly dependent on digital literacy. Pre-service teachers should be familiar with using required software or be taught how to use them. Therefore, using technology has become time-consuming activity. In addition, some planetariums are licensed software; consequently, they should be purchased. This situation might be an obstacle for teacher educators.

The present research was devoted to suggesting another plausible way to enhance pre-service teachers' understanding of the moon's phases concepts. Therefore, the current research focuses on a microteaching environment designed for a science teacher education program. It has been advocated that microteaching is an effective and widely preferred way of preparing pre-service teachers for a classroom environment (Copeland, 1977; He & Yan, 2011; Simbo, 1989). Microteaching provides future teachers with some opportunities to engage in specific teaching techniques, re-organize class activities for their later practice, and practice in a short time and not a crowded audience (Fiorella & Mayer, 2014; Peterson, 1973). Besides its pedagogical contribution reported by an immense body of research (e.g., Boz & Belge-Can, 2020; Durdu & Dag, 2017; Fernández, 2010; Önal, 2019; Subramaniam, 2006), microteaching contributed to student teachers' conceptual understandings in their academic field (Annis, 1983; Fiorella & Mayer, 2014; Roscoe & Chi, 2008; Topping, 1996). As pointed out by Bargh and Schul (1980) and more recently by Fiorella and Mayer (2014), prior to instruction, selecting and organizing teaching material for learners improves the conceptual understanding of the instructor in the intended teaching area. Two factors improve the conceptual understanding of the instructor while presenting the subject matter. Firstly, verbalizing and restating subject matter contributes to instructors' conceptualizations and richer understanding (Bargh & Schul, 1980; Coleman et al., 1997). Secondly, teaching others facilitates social interactions with others. Asking or answering questions, correcting errors, and giving feedback enhance cognitive awareness and conceptual understanding (Bargh & Schul, 1980; Coleman et al., 1997).

The current research contributes to research on pre-service science teachers in two critical ways. Firstly, this research suggests a plausible way to improve pre-service science teachers' understanding of phases of the moon concept. The phases of the moon concept are one of the challenging topics for pre-service science teachers. Researchers on this issue suggested implementing time-consuming and technology-integrated activities for pre-service science teachers. However, implementing these suggested ways is not feasible in many circumstances; therefore, different alternative methods are needed to improve pre-service science teachers' conceptual understanding. Secondly, microteaching is generally perceived as a way to enhance pre-service teachers' pedagogical skills, and its contribution to conceptual understanding is usually neglected. Thus, this research extends previous research about the effectiveness of micro-teaching in enhancing the conceptual understanding of pre-service science teachers. In addition, the potential contribution of micro-teaching to conceptual understanding highly depends on the characteristics of the subject matter. Therefore, it is recommended to test microteaching with different domains and complex topics (Fiorella & Mayer, 2013). The present study explores potential changes in conceptual understandings regarding phases of the moon, considering both the role of micro-teaching and the challenges of teaching phases of the moon.

In this aspect, the following research questions guided this research:

1. What is the conceptual understanding of pre-service primary school science teachers regarding phases of the moon?
2. How do pre-service primary school science teachers' conceptual understanding change through microteaching?

The Perspective of the Current Study on Conceptual Change and Lunar Phases

Concepts are mental units of internal representations (Carey, 2000) and are constituted by different knowledge elements organized differently (diSessa, 1993; Vosniadou & Skopeliti, 2014). Changing concepts is a fundamental way of learning since students' preconceptions or misconceptions about the physical world should evolve to expert understanding. The classical view of conceptual change promotes the idea that intuitive concepts have a coherent structure and are replaced with scientific ones via the cognitive conflict method (Posner et al., 1982). However, more recent studies criticized the classical view and suggested knowledge in pieces perspective. According to this perspective, knowledge consists of multiple fragmented knowledge elements rather than a coherent structure. Individuals absorb new knowledge elements, add them to their existing internal representation, and re-organize them (diSessa, 1993; Vosniadou, 2012). The present research followed the paradigm of knowledge in pieces perspective. In the scope of the current research, engaging pre-service science teachers with microteaching involving preparation, teaching, and interaction ensured an opportunity to re-organize their knowledge elements on phases of the moon concepts.

Conceptual understanding can be tracked by the knowledge analysis method. Describing knowledge elements and their changes is an indispensable part of this method. Accordingly, knowledge elements are bits of a knowledge system, and individuals explain a natural phenomenon by activating and organizing them in a context (diSessa et al., 2004). An activated group of knowledge elements is supposed to fit together to solve a problem, respond to a question, or make sensemaking (Hammer et al., 2005). According to Parnafes (2012), four knowledge categories, propositions, mental images, mental models, and general schemas, are functional to capture conceptual dynamics. Propositions refer to statements that are considered entirely accurate. Individuals acquire propositions and, consequently, personal experience or learning. For instance, students may learn from their textbooks that the moon is the earth's satellite, or they stress that the moon's shape changes gradually depending on their daily moon observations. General schemas are explanations of the working mechanism of things (Parnafes, 2012). For instance, a student may stress that the distance between the moon and the earth determines the moon's shape. Therefore, it is plausible to consider that this student activated a general schema of distance to explain phases of the moon. The mental model corresponds to the dynamic and runnable mental structure created dealing with an issue or responding to a question (Vosniadou & Brewer, 1992). Explanations and demonstrations pertaining to the moon's orbit around the earth can be given as an example of a mental model. The final category is mental images, which refer to static images and snapshots of a concept. For example, students' drawings of different appearances of the moon can be categorized as mental images.

The sun, the earth, and the moon are related to the occurrence of lunar phases. Four mechanisms among these celestial bodies should be noticed to understand why we observe different moon phases (Parnafes, 2012; Trundle et al., 2002, 2007). As seen in Figure 1, while orbiting around the earth, half of the moon is illuminated by the sun. In addition, it should be considered that we only see half of the moon from the earth. Finally, individuals should visualize the lightened side of the moon seen from the earth to determine lunar phases. A total number of four general schemas are necessary to explain this phenomenon. These knowledge elements were entitled "orbit," "illumination," "half," and "apparent." Due to the mechanism explained above, eight different basic moon shapes have appeared from the earth. These different appearances and their names are shown in Figure 1.

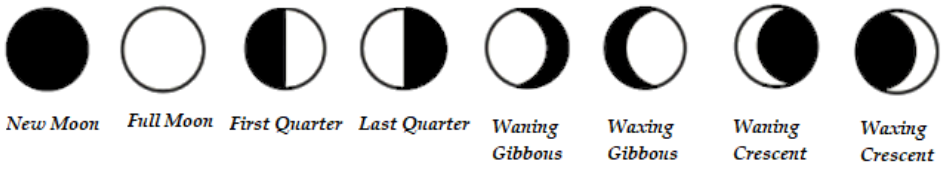

Figure 1. Name and appearance of the lunar phases

It is documented that lunar phases concept is confused with the eclipses concept, not only for children but also for adults. Since both phenomena occur due to the movement of the sun/earth/moon system, individuals cannot differentiate lunar phases from eclipses. A solar eclipse occurs as a result of the occultation of the sun by the moon, and lunar eclipses occur while the moon moves into the earth's shadow cone (Moore, 2000). Lunar eclipses and full moons occur when the earth is located between the moon and the sun, and solar eclipse and the new moon occur when the moon is located between the sun and the earth. Since the moon's orbit is tilted by 5.2 degrees, the shadow of the earth and the moon fall above or below. Therefore, eclipses do not occur once a month. Another problem

detected by the previous studies (e.g., Ogan-Bekiroglu, 2007) is related to the moon's appearance in the daytime. The individual considers that the moon can be observed only at night. However, since its brightness is enough, it is visible when the moon is high enough in the sky. In addition, it is noted that (Parker & Heywood, 1998) awareness of the nature of light, including its rectilinear propagation and reflection from a spherical surface, is crucial to understanding lunar phases.

Research Methodology

Research Design

This research was designed concerning a qualitative case study. Each participant corresponded to the cases of the research. Conceptual understanding related to moon-related topics is complex since different pre-service teachers activate different knowledge elements. These knowledge elements interact with each other and constitute a unique conceptual structure for individuals. Therefore, this research was conducted to provide an in-depth explanation of pre-service science teachers' conceptual understanding.

Participants

Participants of the research were two senior female students in the field of primary school science education. Participants (Eva and Arya as pseudo names) had almost similar experiences in the field of astronomy. They pursued an introductory astronomy course lasting one term in their second year of the undergraduate teacher education program. They have not participated in a training program dealing with astronomy issues provided in out-of-school learning environments. Their knowledge of astronomy stemmed from popular media and undergraduate astronomy courses.

Research Context

Data of the present research were collected at an undergraduate course requiring teaching experience while providing student teachers some opportunities to reflect upon teaching. In the context of the course, pre-service teachers obtained experience in different teaching primary school science topics in a real classroom environment and the faculty class as a microteaching activity. This research was designed to examine the role of pre-service science teachers' microteaching, including teaching, preparation, and social interaction, on the development of conceptual understandings concerning phases of the moon. In this regard, two pre-service science teachers were assigned to teach their classmates phases of the moon topic. After one week of preparation, two pre-service science teachers gave their classmates thirty minutes of instruction. Although eleven pre-service science teachers were pursuing this undergraduate course, the current study examined two pre-service science teachers' instructions on phases of the moon. Since the other micro-teaching activities should be related to physics, chemistry, and biology issues, they were not involved in the current study.

Data Collection Tools

Interviews. Pre-service science teachers were interviewed to map their conceptual understanding before and after microteaching. Both interviews included six main questions based on previous research (Nielsen & Hoban, 2015; Stahly et al., 1999; Trundle et al., 2002) to reveal a conceptual understanding of the moon's phases. Furthermore, each participant was directed to two questions to determine their interest in astronomy in the pre-interview and the sources they utilized for preparation for instruction.

Interviews were designed as semi-structured, requiring further questions to articulate participants' ideas. The pre-service science teachers were interviewed before and after one week of their instructions. Spheres and drawings were utilized to enrich their verbal explanation during the interview, similar to previous research (Barnett & Morran, 2002; Stahly et al., 1999; Trundle et al., 2002). To explain the phenomenon, participants responded to the question

one more time with their illustrations and spheres. Each interview lasting approximately 30 minutes, was video and audio recorded and then transcribed. Interview questions are presented following table.

Table 1. Interview questions

Interview questions
What are the moon's phases?
Can you draw the appearance of the moon for each phase?
What are the names of these phases?
What causes the moon to have different appearances?
Can you draw the mechanism of each phase?
Can you demonstrate how the different phases occur with three-dimensional models?

Observation of Microteaching. Both pre-service teachers' microteaching activities included the names, sequences, and causes of phases of the moon. They preferred student-centered teaching methods enriched by questioning, three-dimensional models, and worksheets. A total of nine pre-service teachers acted in the primary school students' role, and the researchers were in the classroom during their instruction. Pre-service science teachers taught in a technology classroom, including a smartboard and computer. Both researchers and classmates provided feedback at the end of the microteaching activity regarding the only pedagogical aspect of the instruction. Feedback regarding the subject matter was given after completing the research to prevent manipulation of participants' conceptual understanding before the second interview. Microteaching activities were videotaped and transcribed. Researchers focused on pre-service science teachers' verbal explanations, conversations with their classmates, and feedback on classroom activities while analyzing recorded video data.

Data Analysis. The theoretical construct of knowledge in pieces perspective and framework developed by Parnafes (2012) were utilized to describe and compare pre-service science teachers' conceptual understandings before and after microteaching. Inferences were generated from pre-service science teachers' explanations, drawings, and model demonstrations. In other words, to generate inferences, pre-service science teachers' arguments were analyzed as a whole. Therefore, a holistic perspective was followed instead of coding data. As noted before, four general schemas are necessary to produce a scientific explanation of lunar phases. In addition to them, pre-service teachers activated different general schemas. A complete list of the detected general schemas and their descriptions are tabulated in Table 2.

Table 2. Activated general schemas

Shemas	Descriptions
Orbit	The moon orbit around the earth
Illumination	The sun illuminates the moon
Half	An observer from the earth always sees half of the moon
Apparent	The entire illuminated half of the Moon does not always point toward the earth.
Angle	The angle of light received from the moon determines phases.
Blocking	An object can block light from the sun.
Reflection	Different parts of the moon reflect light on the earth to a different extents.
Face	Only the same side of the moon is visible from the earth

Findings

In this section, the findings of the present research were documented concerning two identified cases. Pre-interview, observation of microteaching, and post-interview were presented, respectively.

Case 1

Pre-interview. The results showed that Eva had embryonic ideas about different appearances and causes of the moon phases. Initially, s/he tried to explain why we observe the moon with its various shapes. S/he said, "I think it is related to the relative location of the moon to the earth. I am not sure". Accordingly, Eva attributed the different

phases of the moon to its orbit around the earth. Namely, s/he activated the general schema of "orbit" to explain the moon's phases. Eva could not explain why and how the orbital position leads to different moon appearances due to her superficial understanding. On the other hand, s/he stressed that the shape of the crescent moon changes after days and then becomes a full moon. S/he drew the name and sequence of each phase, as seen in Figure 2.

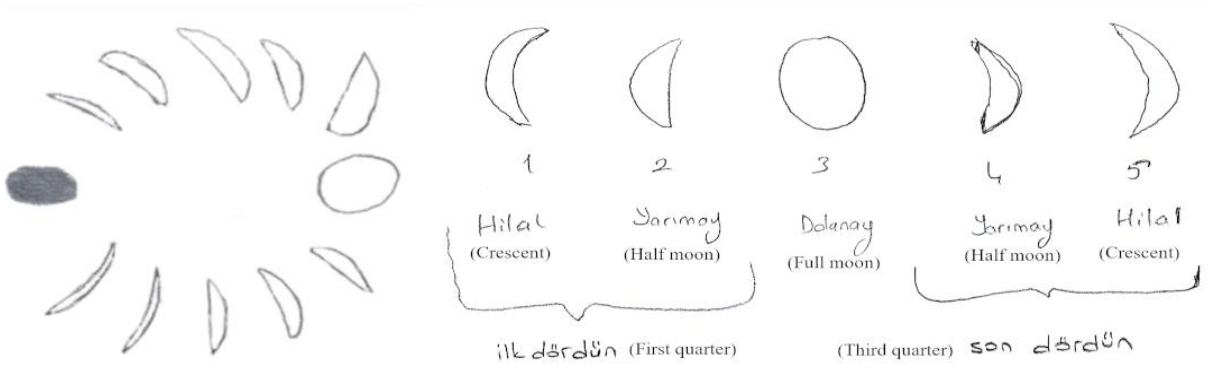

Figure 2. Eva's perspective on the appearance of the moon's phases

Figure 2 shows that s/he was aware of the certain shapes of the moon. The diagram included waxing and waning crescent, first and last quarter, full moon, and new moon. However, waxing and waning gibbous did not exist in these diagrams. Terminological problems also appeared. S/he did not differentiate crescent moons as waxing and waning. In addition, s/he is entitled to the first and last quarter as a half-moon. According to her perspective, the first quarter and last quarter corresponded to crescents and half-moons. Her explanations were based on her limited past observation and terminological similarities among the terms. S/he entitled the first quarter as half-moon and the half-moon and waxing crescent as the first quarter.

Eva was asked to explain different moon phases via the researcher's sun/moon/earth models. S/he did not show specific lunar phases while organizing the positions of the sun/earth/moon models. However, s/he inserted new explanations for the moon's phases. S/he articulated:

> The moon does not have anything. It is just the reflected light of the sun. It should reflect all sunlight to be a full moon. If the moon is right in front of the sun, it may be a solar or lunar eclipse. But I could not memorize what exactly they were.

While explaining the previous utterance, Eva located the moon model between the earth and the sun, corresponding to the new moon phase. In other words, Eva stressed that the moon reflects sunlight from the sun to be a full moon while demonstrating a position where there was any received sunlight to the half of the moon seen from the earth. This situation showed that Eva activated the "reflection" general schema. However, s/he could not visualize how reflection occurs from the moon to earth in three-dimensional nature. Afterward, s/he located the moon behind the earth relative to the sun to show crescent moons. S/he stressed that it is somewhere here but not at an invisible point while pulling over the moon from the line of the earth/sun. S/he noted that the moon could reach the sunlight to its edge in this way. It was revealed that Eva harbors "blocking" general schema. Therefore, s/he avoided locating the moon in line with the earth due to possible inhibition of sunlight by the earth. In other words, s/he considered that the moon could not be seen when it was behind the earth relative to the sun.

From the scientific explanation of the phases of the moon and knowledge in pieces perspective, we can claim that Eva did not have a solid understanding of the moon's phases. It was revealed that the general schemas of "orbit," "blocking," and "reflection" were activated while responding to the interview questions about phases of the moon. S/he tried to explain the phases of the moon concepts via activating these knowledge elements. However, both "blocking" and "reflection" general schemas were not related to the scientific explanation of phases of the moon. Furthermore, Eva's model demonstration showed that s/he could not visualize the spatial characteristics of the sun/earth/moon. S/he stated that the moon reflects the sunlight between the sun and the earth; therefore, we observe the full moon. However, this position corresponds to the new moon since half of the moon we observe is not illuminated by the sun. Eva's mental model regarding phases of the moon and activated knowledge elements is summarized in Figure 3.

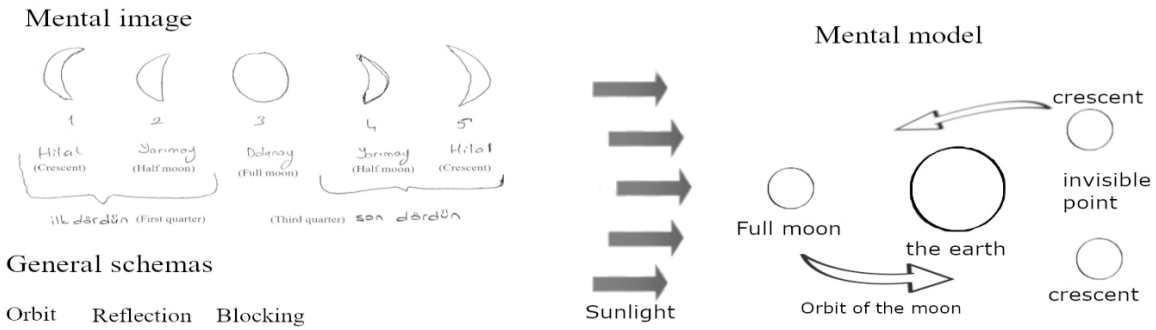

Figure 3. Summary of mental elements activated by Eva

Observation of microteaching and post-interview. The instruction of Eva commenced with introducing different appearances of the moon. S/he stressed:

> Eva: I do not know whether you are interested in moon phases. I have tried to observe the moon for a long time. Now, we are observing the moon with its crescent phases. However, it was different last week. Is there anybody who observes different lunar phases?
> Student 1: Sometimes, it is enormous.
> Student 2: We sometimes could not see the moon.
> Eva: We can start our activities (distributing activity sheets). Could you read the first question?

As seen in the utterance above, Eva explained that the moon had different appearances. Initially, s/he asked the students to draw different shapes of the moon. After drawing each phase, Eva confirmed their appropriateness. It was revealed that students appropriately presented the figure of eight moon phases. Compared with responses in the pre-interview, s/he enhanced mental images of the appearance of lunar phases. Although s/he did not mention the waning and waxing gibbous moon in the pre-interview, these two moon phases took place under Eva's instruction.

After the drawing activity, s/he provided computers with a simulation program and asked students to observe the moon's phases via this software. After the students' examination, Eva directed questions to understand students' ideas on lunar phases. S/he said:

> Eva: We all see the different phases of the moon and draw them on the board. Why did we observe these different shapes of the moon?
> Student 1: The moon revolves around the earth.
> Eva: You say we observe phases since it revolves around the earth. Are there any explanations? Is there anything you want to add to this explanation?
> Student 2: While revolving, the part of the moon that receives sunlight changes. Therefore, we observe the phases of the moon.
> Eva: Is there anybody who explained it better? Look at the board (showing simulation). You can observe how the sunlight comes and the movement of the moon. While changing the position of the moon, phases also change. Why does this happen?
> Student 3: It is also related to our viewpoint. I mean that extent of the moon that we observe from our location determines moon phases. We observe the side closest to us divided by a green line (Eva changed the moon's position to the new moon). The part of the moon that is closest to us is dark. Therefore, it is the new moon.
> Eva: Yes, that is right. Since the moon's light could not reach, we observed the new moon. Here (full moon position), the part of the moon that we see receives all the sunlight. Do you understand?

The utterance above showed that Eva and Eva's classmates appropriately pointed out the factors behind the moon's phases. Eva's classmates explained, and Eva confirmed that the moon orbits around the earth (orbit), half of the moon was observed from the earth (half), half of the moon is illuminated by the sun (illumination), and illuminated part of the moon we observe from the earth (apparent) refers to the phases.

Post-interview conducted with Eva also showed that s/he changed her ideas from the pre-interview. S/he again explained the appropriate names of each different phase and their sequences. Her explanation regarding the moon's phases is shown in the following utterance.

> The location of the moon is essential. I want to explain it by showing these two examples (full moon-new moon). Considering these objects like the moon/earth/sun, the side of the moon we see receives sunlight; therefore, we see the moon as a full moon. On the other hand, the side of the moon illuminated by the sun is here, but we cannot see this part. The part we see does not receive sunlight; therefore, we cannot see the moon. The moon is the satellite of the earth and orbits around the earth. Depending on its different positions, we see it with its different shapes. It reflects the sunlight received from the sun, and we see.

As seen in the excerpt above, Eva appropriately explained the new moon and full moon phases. S/he considered the moon's orbit around the earth and illuminated part of the moon. Then, s/he considered the part of the moon we see from the earth to predict the moon's phases. After Eva discussed different moon appearances, s/he asked students to entitle the appearance of different phases. Students were appropriately entitled to eight different phases of the moon. Figure 4 presents the summary of Eva's activated mental elements.

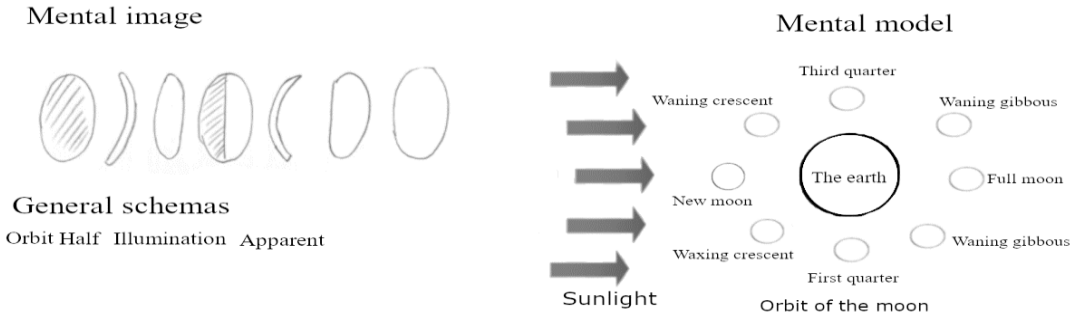

Figure 4. Summary of Eva's conceptual understanding

As shown pre-interview segment, s/he activated "orbit," "reflection," and "blocking" general schemas while explaining phases of the moon. Comparing Eva's instruction and post-interview with her pre-interview, it was revealed that s/he deactivated "reflection" and "blocking" general schemas and activated "half," "illumination," and "apparent" general schemas. In addition, s/he appropriately explained the reasons behind the moon's phases via her mental model.

Case 2

Pre-interview. Analysis of Arya's explanation and drawings showed that s/he also has a superficial understanding of lunar phases. Explanation of Arya regarding phases of the moon covered several related and unrelated knowledge elements with moon phases. S/he activated the general schema of "illumination" and "half" in her explanation. S/he articulated,

> Sunlight illuminates the moon. The moon reflects the sunlight to us from the part we see. We also see the same face of the moon. Because of the different angles of sunlight (received from the moon), we observe the moon with its different phases.

As seen in the excerpt above, Arya also considered that the angle of sunlight reflected by the moon is associated with moon phases; we observe only one face of the moon (face), and the moon reflects sunlight (reflection). In other words, Arya activated only the "illumination" general schema, which is necessary to explain phases of the moon considering the excerpt above. Other activated general schemas such as "face," "angle," and "reflection" are not directly associated with lunar phases. According to normative scientific explanation, we observe only one side of the moon. This situation is related to the fact that the moon's spin and orbit around the earth take the same time. Although Arya considered this fact, there is no direct relationship between the appearance of the same face of the

moon and lunar phases. In addition, the angle and amount of the reflected light are not the factors that determine phases of the moon.

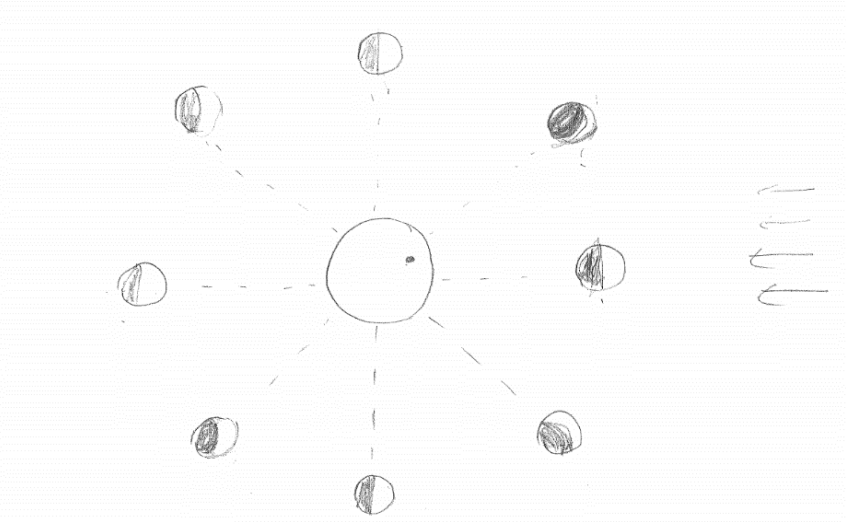

Figure 5. Arya's perspective on the appearance of the moon phases

In addition to the explanation above, Arya drew Figure 5, which indicates her mental image. On the one hand, s/he showed different appearances of the moon while orbiting. Therefore, it was revealed that s/he activated the "orbit" general schema. Figure 5 also showed that Arya was aware of each phase's appropriate sequence and name. On the other hand, s/he confused the space-based and earth-based appearance of the moon. According to a space-based demonstration, half of all moons closest to the sun must be illuminated, while the other half is dark. Since an observer observes the phenomenon from the top of the sun/moon/earth system, s/he only observes that half of the moon is illuminated by the sun. The moon's appearance from the earth is generally demonstrated separately, as seen in figure 8. However, considering Figure 5, some of the moon shapes have greater illuminated parts while some have less, which is the moon's appearance from the earth, not space. In other words, although Arya drew a space-based demonstration of the moon's phases, s/he inserted the earth-based appearance of lunar phases in her demonstration. The shape of the gibbous moons, which resemble a thick crescent moon, is another problem in Arya's drawing. Figure 6 shows a summary of Arya's understanding of the lunar phases.

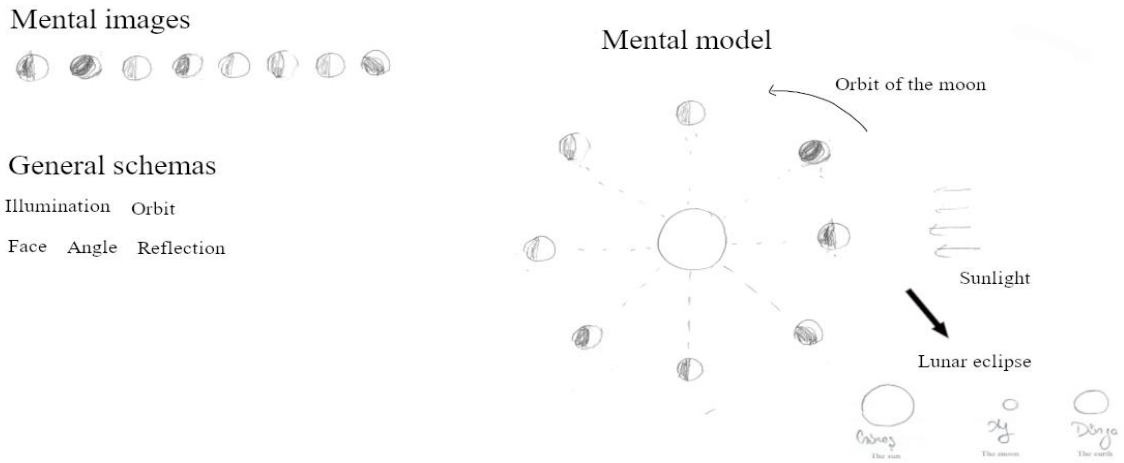

Figure 6. Summary of Arya's conceptual understanding

Observation of microteaching and post-interview. Arya explained that the moon revolves around the earth at the beginning of instruction. S/he designed role-playing activity with three students acting as the moon, the earth, and the sun. The students performed as the moon held a half-black ball. Arya stressed that the black part of the moon corresponded to half of the moon, which does not receive sunlight. The student acted as the moon revolved around

the earth and spun the ball in her hands. The student acting as the earth explained what s/he observed and drew them on the board. At the end of the activity, the student drew eight different appearances of the moon. Arya noticed the shape of the waning gibbous moons was not appropriate. S/he corrected it, as seen in Figure 7.

Figure 7. Change of appearance of the waning gibbous moon

As shown in Figure 7, the student drew waning gibbous moons as it was a concave appearance (on the left side). Arya realized this mistake and changed the appearance of gibbous moons from concave to convex, which is seen on the right of Figure 7. This situation showed that Arya has appropriate mental images of the moon's phases. Therefore, s/he realized students' mistakes and corrected them.

After this activity, Arya demonstrated a video including the change in the moon's phases while the moon orbits around the earth. After the video, Arya explained why we observed the moon phases, as shown in the excerpt below.

> As seen from the video, suppose that sunlight comes from this side (illumination), and the moon revolves around the earth (orbit). While the moon revolves, only half of it receives sunlight (half). The shape of the half that we always observe changes (apparent). In other words, the illuminated portion of the half that we see changes since the moon's orbit around the earth.

Arya enhanced her understanding of the moon's phases compared to the pre-interview. "Orbit," "half," "illumination," and "apparent" general schemas were activated. S/he deactivated the "face," "angle," and "reflection" general schemas while explaining the phases of the moon. Dialogs between Arya and her classmates also indicated that Arya improved her understanding of the moon's phases.

> Arya: Who can tell me why we observe lunar phases?
> Student 1: The moon spins and orbits around the earth. Considering the moon, the earth, and the sun, it changes depending on sunlight. It also orbits around the earth. It prevents.
> Arya: Is there someone else? You should have understood the issue after my explanation.
> Student 2: We observe only one face of the moon. We observe the moon's phases since sunlight arrives and the moon orbits.
> Arya: That is right. If the moon did not orbit around the earth, we would not observe the moon's phases. Your friend's explanation (student 1) reminds me of a critical aspect of the issue. Your friend said that the earth prevents the moon. What do you think about that? Might different appearances of the moon may be related to the shadow of the moon?
> Student 3: It is related to the moon's position in the earth's orbit.
> Arya: Absolutely; the moon's position determines the moon's phases. The invisible part of the moon is not because of the moon's shadow.

Utterance above showed that both Arya and her classmate focused on the moon's orbit around the earth and the moon's illumination as a reason for the moon's phases. One student emphasized the moon's phases occur due to the

prevention of the moon by the earth. S/he explained that the shadow of the moon was not a reason for the phases of the moon. This situation showed that Arya differentiated eclipse concepts from lunar phases.

Arya explained the names and sequences of the moon phases and why we observe these different appearances while utilizing the same video. Then, s/he finalized her micro-teaching instruction with a worksheet, including an activity regarding the puzzling change of moon phases. As seen in Figure 8, s/he designed this activity considering different perspectives. In other words, s/he differentiated the space-based appearance of the moon from its earth-based appearance. Compared to the pre-interview, her understanding improved concerning spatial characteristics of celestial bodies.

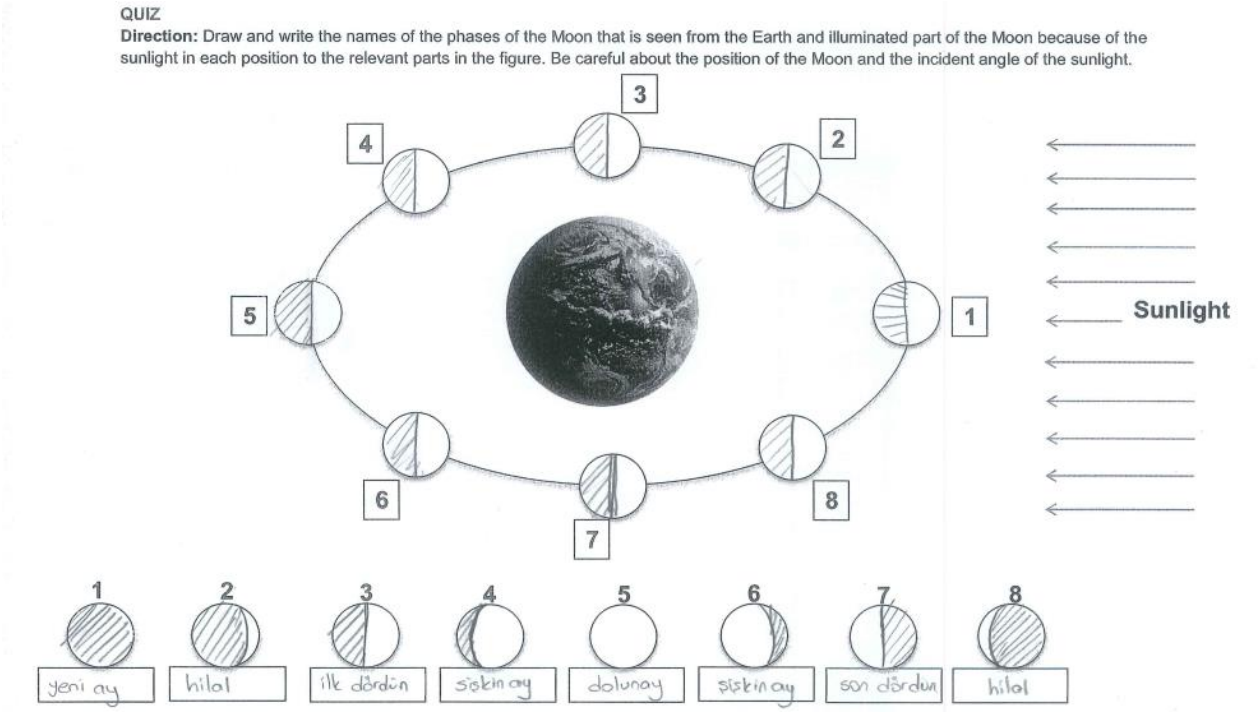

Figure 8. Sample activity sheet

In the second interview, Arya also responded to the interview questions confidently. S/he accurately indicated which part of the moon is illuminated and which is seen from the earth. Arya's drawing and explanations are summarized in Figure 9.

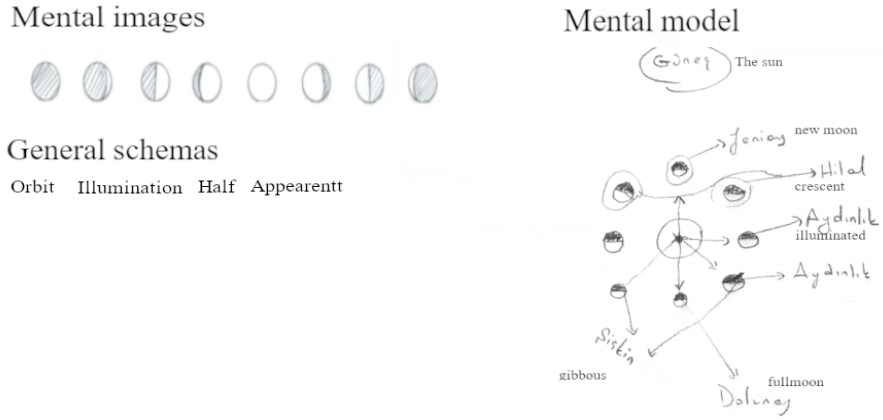

Figure 9. Summary of Arya's conceptual understanding

Discussion

This research attempted to examine pre-service primary school science teachers' conceptual understandings regarding phases of the moon. It was also intended to demonstrate the reflections of microteaching on their conceptual understandings. It was revealed that pre-service science teachers possessed different and superficial understandings concerning phases of the moon. After engaging in a microteaching process, pre-service science teachers improved their understanding. They activated all necessary general schemas for normative scientific understanding of lunar phases. In addition, the detected general schemas and mental images appropriately described lunar phases. At this point, it was found that engaging with microteaching activities improves pre-service science teachers' understanding of lunar phases. The quality and quantity of knowledge elements activated by pre-service science teachers increase after microteaching. Studies on conceptual change (diSessa, 1993; Vosniadou, 2012) stated that individuals re-organize their conceptual understanding due to daily life experiences. It was plausible to conclude that engaging with microteaching ensure learning opportunity for pre-service teachers. Therefore, they reached a more sophisticated understanding of lunar phases by activating necessary general schemas and deactivating unnecessary general schemas.

The current research findings were consistent with previous studies (e.g., Abell et al., 2002; Bell & Trundle, 2008), which showed pre-service teachers improved their understanding after engaging in inquiry-based activities. However, this research reported that pre-service science teachers could improve their understanding without different approaches requiring long periods and the ability to use technological devices. Specifically, pre-service science teachers stimulated their conceptual understanding with their preparation to teach and microteaching practices. These results were not surprising since pre-service science teachers whose age was approximately twenty years old had more life experience and awareness of their knowledge compared with preschool, primary school, and high school students. Motivating or engaging pre-service science teachers in microteaching may improve their conceptual understanding.

Previous research studies pointed out that teaching to others contains preparation, instruction, and interaction segments (Bargh & Schul, 1980) and could be a significant agent in developing conceptual understandings of various topics (Fiorella & Mayer, 2013, 2014). Pre-service science teachers engaged in microteaching activities in the current research also included preparation, instruction, and social interaction. Pre-service teachers who participated in the present research searched about teaching methods, materials, books, and videos to improve the quality of their presentations. Then, they instructed phases of the moon topic and verbalized related concepts. Instruction to their classmates contained social interaction, such as asking questions, responding to questions, or giving examples. Thus, improving the conceptual understanding of pre-service science teachers may be related to all three steps: social interaction, instruction, and preparation. However, this study did not design to examine the potential contribution of different steps of microteaching. Therefore, it was impossible to determine which part of microteaching was more effective in enhancing pre-service science teachers' understanding of phases of the moon concept in the context of the current study. On the other hand, the present study was conducted with two pre-service science teachers with almost the same level of experience in astronomy issues. The role of micro-teaching in the conceptual change of pre-service science teachers who had different experiences could not be observed in the context of the current research. It was recommended for future research to examine and compare the contribution of different microteaching steps to the development of conceptual understanding of a great number of pre-service science teachers. In this way, teacher educators may design their microteaching activities more effectively considering the potential contributions of these steps.

The present research also indicated that the pre-service teachers were not equipped with substantial observational knowledge of the sky. For instance, pre-service science teachers could not show different appearances of the moon during a month at pre-interview. The lack of observational knowledge of science teachers was documented in the previous research. For instance, Mant and Summers (1993) showed that teachers could not explain the apparent daily movement of the moon and other celestial bodies. This problem was generally attributed to the lack of experience in sky observation (Mant & Summers, 1993). It was revealed that pre-service science teachers' experience in sky observation was indispensable to properly understanding astronomy topics. Thus, pre-service science teachers should be motivated to observe the moon and other celestial bodies.

Previous studies reported that teaching others contributed to conceptual understanding. Since the contribution highly depended on the characteristic of subject matter knowledge, research about the effectiveness of microteaching on

different domains was suggested (e.g., Fiorella & Mayer, 2013). According to the current research, it was revealed that pre-service science teachers improved their understanding of the concept of the lunar phase after engaging in microteaching. To be more specific, pre-service science teachers appropriately explained the name and sequence of lunar phases and the rationale behind the different appearances of the moon. As aforementioned, different spatial abilities, such as spatial transformation, spatial projection, and geometric spatial ability, were required to understand the moon's phases. Compared with the pre-interviews, pre-service science teachers had better performance with respect to their spatial ability. To cite an example, they demonstrated the moon's appearance from the earth and space to their classmates. In addition, Arya corrected her classmates' drawings of the gibbous moon from concave shape to convex. These situations showed that pre-service science teachers utilized the necessary spatial abilities to teach phases of the moon. Therefore, it was plausible to consider that the pre-service science teachers also enhanced their spatial abilities during the microteaching process.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors

Acknowledgments

Ethical approval. All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.
Data availability. Data generated or analyzed in the current research is available from the authors on request.
Conflict of interest. The authors declare that they have no conflict of interest.

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The Impact of Social Interaction, Academic Achievement, and Cognitive Flexibility Levels on Clinical Reasoning: Statistical Discourse Analysis

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Abstract

This study aims to analyze the impact of intern physicians' social interaction during teamwork, their cognitive flexibility and academic achievement on clinical reasoning. The study, designed through sequential exploratory mixed method, was carried out with 20 intern physicians working in 4 teams. The process of how they approach to the case was recorded. The verbal interactions made during the discussions in the teams were analyzed, the discourses obtained from the videos were coded and modelled by regression. In addition, the cognitive flexibility and academic achievement levels of intern physicians were also included in the regression modelling. The results showed that, according to the initial signs and symptoms of the first period of the case (when uncertainty was high), the team members informing each other resulted in success in clinical reasoning. Although guiding in the first period was not very effective, excessive guiding in the second period played a negative role in clinical reasoning. In the second period, ignoring, reminding, and suggesting had a negative impact on clinical reasoning. Our study demonstrated that academic achievement and cognitive flexibility levels of the students in teamwork has a positive impact on the quality of clinical reasoning. Moreover, for effective clinical reasoning, the quality of discourses in the team is more important than how many discourses are created during the discussions.

Introduction

In accordance with andragogy and learner-centred paradigms, one of the most common approaches used in medical education is problem-based learning (PBL) (Servant Miklos, 2019). Although PBL has various types of implementations (case-based, project-based, etc.) and may be structured at different levels (Moesby, 2004), it has some common key characteristics in terms of learner-centeredness, small group/team learning, educators as facilitators or guides, problems as a starting point for learning and a tool to develop clinical problem-solving skills, knowledge acquisition through self-directed learning (Barrows 1996). When these characteristics are put together, medical students should develop certain skills such as communication, collaborative inquiry, critical thinking, creative problem solving, decision-making and clinical reasoning (CR).

Clinical reasoning (CR) can shortly be defined as “diagnostic problem solving” process (Schwardz & Elstein, 2004) during which a physician encounters a patient and tries to understand the possible causes of the patient complaints or abnormal conditions he or she has, makes diagnosis, and takes the actions to be able to manage the case (ten Cate, 2017). The basic principles of CR include the following (Irfan, 2019):

1. Try to come up with a provisional diagnosis using the data of the patient.
2. Determine the severity of the illness and make a comparison between the data of the patient and your provisional diagnosis.
3. Improve the diagnosis through further data from the literature and previous clinical examination.
4. Have further investigation based on this working diagnosis.
5. Go over the diagnosis according to the investigations and treatment responses.
6. Have a thought-provoking monologue so that your colleagues can correct any faulty models of thinking.

Since CR, which is an essential skill in health professions (Cambron Goulet et al. 2019; Higgs & Jensen, 2019), is a complex process which allows the physicians to combine scientific knowledge, clinical experience and critical thinking considering all the information they have about the patient (Rutter & Harrison, 2020), it requires the use of higher-order thinking skills (Laverty & Thompson, 2020). Higher-order thinking skills

involve effortful, nonalgorithmic thinking, judgments about complex problems, and consideration of multiple solutions through self-regulation of knowledge construction (Hmelo & Ferrari, 1997; Richards et al., 2020). Similarly, cognitive flexibility (CF) is another multidimensional process which involves processing multiple pieces of information at the same time, generating multiple ideas, considering alternatives, and altering or changing plans to adjust to a particular situation or context (Stevens 2009). CF involves selecting the knowledge to adaptively fit the needs of understanding and decision-making in a situation; therefore, it depends on having a diversified repertoire of ways of thinking (Spiro, 1988). As CF helps individuals make adaptive responses to complex phenomena (Spiro et al., 2003), it is a very important term used in medical education.

Considering the uncertain conditions in the diagnosis and treatment process of a patient, we can conclude that medical students need to develop higher-order thinking skills for their profession. This type of development depends on the curriculum and strategies used to encourage learners to take responsibility for their own learning through engagement (Theobald and Ramsbotham 2019) and social interaction through effective teamwork.

As physicians often work in teams in clinical settings, learning in teams and teamwork is another crucial competence that intern physicians should develop (Rachael et al. 2010). In addition, learning in teams has a positive impact on students' CR skills (Jost et al., 2017). In teamwork, during which group members have an active and constructive cooperation and communication the distribution and exchange of information among group members is of great importance for an efficient CR process (Fürstenberg et al., 2019). This type of engagement during teamwork is a form of social interaction, and the language used in that kind of interaction is viewed as discourse (Rachael 2008). In other words, discourse can be described as the process team members put effort to understand each other and reach a consensus (Bossche et al., 2006). In process of discourse, students collaboratively inquire, elaborate, and evaluate each other contributions to have a common understanding about an issue (Lu et al., 2011). This study aims to analyze the impact of social interaction among intern physicians during teamwork, their cognitive flexibility (CF) and academic achievement (AA) levels on their clinical reasoning (CR) skills.

Method

This research is a correlational study examining the relationships between teamwork, cognitive flexibility (CF), academic achievement (AA) and clinical reasoning (CR) level.

Participant

The purpose of research and how to conduct it was explained to 20 participants (year-6 medical students as intern physicians), who filled out the consent form to voluntarily participate in our study. The participants formed a team of 5 members. The researchers did not interfere with the team formation process.

Data Collection Tools

Intern physicians' discussions on the case were obtained through a structured scenario created by researchers who are experts in the fields of emergency medicine, medical education, and educational sciences. Apart from the researchers, the case was checked by 3 emergency medicine and 2 medical education experts. Then, the case was revised according to the views of the experts (see Appendix 1). Cognitive flexibility (CF) level of intern physicians was determined by the "Cognitive Flexibility Scale" developed by Martin and Rubin (1995) and adapted to Turkish by Altunkol (2011). This Likert type scale consists of 12 items. Validity and reliability results of the adapted scale were provided by Altunkol (2011). AA levels of the intern physicians were obtained from Medical School Student Affairs Office. The GPA (grade point average) scores of the intern physicians (by the time the study started) were used as their AA level.

Process

- A case was created by the researchers to collect data for the clinical reasoning (CR) process.
- Two emergency medicine specialists and an educational scientist were consulted regarding the case (Validity and Reliability Issues).
- The case was revised according to experts' views.

- To start the research, Clinical Research Ethics Committee's approval was received. (Ethical Issues in Scientific Research).
- Intern physicians were informed about the research. (Ethical Issues in Scientific Research).
- 20 intern physicians who volunteered to participate in the study were decided (Ethical Issues in Scientific Research).
- Intern physicians were asked to form teams of 5 members (the researchers did not interfere with this process).
- The same case was given to 4 teams at the same time and the videos were recorded in four different rooms.
- Before the teamwork, intern physicians were informed about what researchers expect them to do.
- Intern physicians were given 30 minutes to discuss about the case.
- This 30-minute period was divided into 3 periods of 10 minutes.
- In the first period, according to the case given, intern physicians were in charge of the emergency department at a city district hospital. The symptoms of the case given were described as the first cycle of the clinical case (see Appendix 1). The teams worked on the case for 10 minutes, and then were asked to discuss and write down their preliminary diagnoses by stating the reasons for each diagnosis, the anamnesis findings to distinguish this diagnosis from other preliminary diagnoses, physical examination findings and further examinations they may ask for.
- In the second period, according to the case, intern physicians are in charge of the emergency department of a university hospital in a city. The patient was still complaining about the same problem, and so the patient came to the university hospital where the intern physicians work.
- In the second period, intern physicians worked for 10 minutes on additional symptoms and extra information presented to them. Intern doctors were not allowed to change the preliminary diagnoses they made in the first period (while they were in charge of the city district hospital). Given the new symptoms and extra information, the intern physicians were asked to discuss and write down about whether their preliminary diagnoses are still the same or have changed by stating the reasons.
- In the third period, while the patient was still in the university hospital emergency room, some additional information was presented to the intern physicians (see Appendix 1). In addition, in accordance with the latest information provided, the intern physicians were asked to discuss and write about "the final diagnosis for the patient and why they think so", "what should be done to evaluate the diagnosis process of the patient and to better manage this process".
- The whole process was video recorded with professional microphones to enhance the quality of the voice of participants (Validity and Reliability Issues).
- The recordings were put into a text format by the researchers (describing the gestures, mimics, and humors) (Validity and Reliability Issues).
- Each team assigned one member to read the question from the paper. These members read the questions in each period. In other words, considering the case had three periods and four teams, totally 12 questions were read. These discourses were coded as "reading questions" and were excluded from the analysis.
- There were a few incomprehensible discourses realized during listening and transcribing the audio recording. These discourses were coded as "incomprehensible" and were excluded from the analysis.
- After "incomprehensible discourses" and "reading questions" were excluded from the analysis, remaining 625 discourses were coded and analyzed.
- Discourses were coded by researchers. Coding was carried out as follows:

Intern 1: Let's focus only on inferior MI (Suggesting)
Intern 2: Okay (Confirming)
Intern 1: Why did we focus on inferior MI? If we look at it, the patient is 64 years old (Guiding)
Intern 1: Advanced age factor… (Providing Additional Information)
Intern 3: There is effort, and pain while walking (Guiding)
Intern 2: There is pain. OK... There is breathing (Providing Additional Information)
Intern 1: There is also dyspnea (Providing Additional Information)
Intern 2: He has dyspnea… Epigastric region… (Confirming)
Intern 1: Yes (Confirming)
Intern 3: In my opinion, not totally recovered with drugs… (Guiding)
Intern 1: Yes, exactly (Confirming)

- Apart from the researchers, discourses were independently coded by 5 different experts (3 emergency medicine specialists, 1 qualitative research expert especially in discourse analysis, and 1 educational scientist). Qualitative codes (suggesting, confirming, guiding, etc.) given to the discourses were converted into numerical

code and code consistency was calculated through Krippendorff Alpha coefficient. The consistency level was measured as .87 (Krippendorff, 2004) (Validity and Reliability Issues).

- Very few inconsistent codes were found between the codings performed by the external experts and the researchers. A panel was held on which final code would be given to these preliminary codes. In this panel, the final code to be given was determined through discussion (Validity and Reliability Issues).
- The teams' responses regarding the case were scored according to the CR scoring criteria (see Appendix 1).
- The codes related to discourses, the CR scores obtained from the teams' approach to the case, AA, and the scores the intern physicians got from the CF scale were transferred to the statistical package program.

Data Analysis

The case on which intern physicians work and clinical reasoning (CR) process consisted of three periods. First period was the discussion of preliminary diagnoses, reasons, anamnesis, and further examinations they may ask for; second period was the discussion about whether the preliminary diagnoses made in the first period were getting stronger with newly added information and symptoms; the third period was the final diagnosis in the light of the new information and symptoms and the discussions in the first two periods. In each period, new information was added to the case and the discussion took on a new dimension. Therefore, discourses were divided into three (discourses in the first, second and third period). The impact of the discourses on CR was taken into regression modelling for three periods separately. Linear regression was used as CR, which is the output variable, is a success grade and is a continuous variable as well as cognitive flexibility (CF) and academic achievement (AA) as predictor variables. However, discourses in predictor variables are categorical (informing, responding, correcting, etc.). Therefore, discourses were included in the regression model as dummy (dichotomous) variable (Keith, 2019; Warner, 2008). In the regression analysis, autocorrelation (multicollinearity) analysis was performed between predictors. Variance Inflation Factor (VIF) values were very close to 1. So, it was decided that there was no autocorrelation between the predictors (Demaris, 2004; Pedhazur, 1997).

Results

The quantity and types of discourses in each team, and CR scores obtained from the teams were separately analyzed for each period. The results are displayed in Table 1. The following are the results obtained according to discourses that emerged in the CR process in four teams:

- The quantity of discourses in the team is not a guarantee of success in CR. High CR scores were observed both in the team with a high number of discourses and in the team with a low number of discourses. On the other hand, the team with the lowest CR score was the one which had the highest number of discourses (219).
- It was found that the team with the highest CR score used informing in the first and second period. Other teams did not use informing.
- The team with the lowest CR score was the one that mostly used confirming (15.1%) and suggesting (15.1%) in the first period. The same team was the one that used suggesting (16.7%) most in the second period.
- The team with the highest CR score was the one that used guiding (31.3%) most in the first period. The same team was the one that used guiding (20.5%) less than other teams in the second period. The teams which had the lowest score in CR continued to use guiding more (35.2% and 41.9%). In the last period, the team with the highest score in CR and the team with the third high score continued to use excessive guiding (33.3%).
- The team with the highest CR score in the second period was the one that used objecting (22.7%) and confirming (20.5%) most.
- The team with the lowest CR score in the last period was the one that used reminding (13.6%) most.

CF and AA levels of the participants were analyzed. The results are summarized in Table 2.

The lowest score obtained from the CF scale was 12, and the highest score was 72. Achievement scores were given out of 100. The data revealed that high CR scores were obtained in the teams with high CF and AA levels. In each period, the level of CF, AA, and CR of discourse in the teams were individually analyzed. The regression analysis results are summarized in Table 3.

Table 1. Discourse types and CR scores within periods

Period	Discourse		Group 1 f (%)	Group 2 f (%)	Group 3 f (%)	Group 4 f (%)
1	Informing		4(8.3)	---	---	---
	Responding		1(2.1)	1(0.8)	6(5.7)	---
	Correcting		1(2.1)	3(2.5)	7(6.6)	---
	Providing Additional Information		4(8.3)	13(11)	14(13.2)	1(4)
	Ignoring		1(2.1)	7(5.9)	7(6.6)	---
	Reminding		---	---	1(0.9)	2(8)
	Objecting		---	8(6.8)	2(2.8)	---
	Confirming		7(14.6)	22(18.6	16(15.1)	---
	Suggesting		9(18.8)	14(11.9)	16(15.1)	5(20)
	Asking Question		3(6.3)	24(20.3)	13(12.3)	12(48)
	Asking Question + Informing		---	---	---	---
	Asking Question + Guiding		1(2.1)	---	---	---
	Guiding		15(31.3)	26(22)	23(21.7)	5(20)
		Total	48(100)	118(100)	106(100)	25(100)
2	Informing		3(6.8)	---	---	---
	Responding		1(2.3)	1(2.1)	3(5.6)	---
	Correcting		---	4(8.5)	1(1.9)	3(9.7)
	Providing Additional Information		2(4.5)	10(21.3)	4(7.4)	2(6.5)
	Ignoring		1(2.3)	1(2.1)	3(5.6)	---
	Reminding		---	---	2(3.7)	3(9.7)
	Objecting		10(22.7)	5(10.6)	1(1.9)	2(6.5)
	Confirming		9(20.5)	6(12.8)	5(9.3)	2(6.5)
	Suggesting		3(6.8)	6(12.8)	9(16.7)	3(9.7)
	Asking Question		6(13.6)	4(8.5)	7(13)	3(9.7)
	Asking Question + Informing		---	---	---	---
	Asking Question + Guiding		---	---	---	---
	Guiding		9(20.5)	10(21.3)	19(35.2)	13(41.9)
		Total	44(100)	47(100)	54(100)	31(100)
3	Informing		1(2.6)	---	---	1(3.7)
	Responding		---	---	5(8.5)	2(7.4)
	Correcting		---	2(7.4)	3(5.1)	---
	Providing Additional Information		3(7.7)	8(29.6)	6(10.2)	1(3.7)
	Ignoring		3(7.7)	1(3.7)	2(3.4)	---
	Reminding		---	---	8(13.6)	1(3.7)
	Objecting		5(12.8)	1(3.7)	4(6.8)	---
	Confirming		5(12.8)	4(14.8)	5(8.5)	---
	Suggesting		5(12.8)	5(18.5)	5(8.5)	5(18.5)
	Asking Question		4(10.3)	2(7.4)	8(13.6)	6(22.2)
	Asking Question + Informing		---	---	---	2(7.4)
	Asking Question + Guiding		---	---	---	---
	Guiding		13(33.3)	4(14.8)	13(22)	9(33.3)
		Total	39(100)	27(100)	59(100)	27(100
		General Total	*131*	*192*	*219*	*83*
		Clinical Reasoning Score	16	14	10	13

Table 2. CF and AA scores of the interns in teams

Teams	Intern	CF	AA	Team Cog. Flexibility $\bar{X}$ (S)	Team Achievement $\bar{X}$ (S)	Team CR Score
1	Intern 1 (Male)	59	76.27	52 (5.95)	75.34 (2.77)	16
	Intern 2 (Female)	52	71.26			
	Intern 3 (Female)	49	77.08			
	Intern 4 (Female)	43	78.14			
	Intern 5 (Female)	45	78.14			
2	Intern 6 (Male)	55	74.63	49.55 (4.92)	76.29 (3.31)	14
	Intern 7 (Male)	49	81.86			

	Intern 8 (Female)	52	72.45			
	Intern 9 (Female)	48	81.09			
	Intern 10 (Female)	43	74.48			
	Intern 11 (Male)	49	72.62			
	Intern 12 (Female)	48	71.19			
3	Intern 13 (Female)	45	71.06	47.06 (1.66)	72.24 (2.23)	10
	Intern 14 (Male)	48	70.90			
	Intern 15 (Male)	45	77.69			
	Intern 16 (Female)	47	69.27			
	Intern 17 (Male)	46	72.64			
4	Intern 18 (Female)	46	74.62	49.95 (5.4)	72.81 (2.55)	13
	Intern 19 (Male)	59	71.02			
	Intern 20 (Female)	49	77.08			

Table 3. The prediction level of the discourses, CF, AA on CR in three different periods

Period	Predictor Variables	β (95% CI)	t	p	R	R^2	Model ANOVA F (p)
	Constant	-17.45 (-22.59, -12.31)	-6.68	<0.0001			
	Informing	2.79 (0.95, 4.64)	2.99	0.003			
	Responding	-1.15 (-2.50, 0.19)	-1.69	0.093			
	Correcting	-0.92 (-2.09, 0.26)	-1.53	0.127			
	Providing Additional Information	-0.23 (-1.03, 0.57)	-0.57	0.571			
	Ignoring	-0.24 (-1.28, 0.81)	-0.45	0.653			
1	Reminding	-0.77 (-2.88, 1.34)	-0.72	0.472	0.62	0.39	12.75 (<0.0001)
	Objecting	-0.09 (-1.27, 1.08)	-0.16	0.876			
	Confirming	0.07 (-0.66, 0.79)	0.18	0.855			
	Suggesting	0.16 (-0.57, 0.89)	0.43	0.668			
	Asking Question + Guiding	0.93 (-2.68, 4.54)	0.51	0.612			
	Guiding	0.21 (-0.44, 0.86)	0.64	0.522			
	Cognitive Flexibility	0.17 (0.12, 0.22)	7.05	<0.0001			
	Achievement	0.29 (0.23, 0.36)	9.37	<0.0001			
	Constant	-14.79 (-21.67, -7.93)	-4.26	<0.0001			
	Informing	1.69 (-0.55, 3.95)	1.49	0.138			
	Responding	-2.13 (-3.93, -0.33)	-2.34	0.020			
	Correcting	-0.98 (-2.48, 0.52)	-1.29	0.198			
	Providing Additional Information	-0.91 (-2.06, 0.24)	-1.56	0.121			
2	Ignoring	-2.02 (-3.81, -0.22)	-2.22	0.028	0.64	0.41	9.40 (<0.0001)
	Reminding	-1.95 (-3.75, -0.14)	-2.12	0.035			
	Objecting	0.33 (-0.83, 1.49)	0.57	0.571			
	Confirming	0.03 (-0.57, 0.63)	0.25	0.886			
	Suggesting	-1.43 (-2.53, -0.32)	-2.55	0.012			
	Asking Question	-0.72 (-1.84, 0.40)	-1.27	0.206			
	Guiding	-1.14 (-2.07, -0.22)	-2.44	0.016			
	Cognitive Flexibility	0.16 (0.11, 0.21)	5.79	<0.0001			
	Achievement	0.28 (0.19, 0.36)	6.71	<0.0001			
	Constant	-24.59 (-33.08, -16.12)	-5.73	<0.0001			
	Informing	1.63 (-1.17, 4.44)	1.15	0.252			
	Responding	-0.986 (-2.66, 0.68)	-1.17	0.245			
3	Correcting	-0.98 (-2.86, 0.91)	-1.02	0.309	0.68	0.41	8.97 (<0.0001)
	Providing Additional Information	0.30 (-0.95, 1.56)	0.48	0.632			
	Ignoring	1.39 (-0.36, 3.16)	1.57	0.119			
	Reminding	-1.25 (-2.79, 0.29)	-1.60	0.112			

Objecting	0.10 (-1.35, 1.56)	0.14	0.887
Confirming	0.35 (-0.95, 1.66)	0.54	0.594
Suggesting	-0.29 (-1.33, 0.74)	-0.56	0.575
Asking Question	0.03 (-1.17, 1.22)	0.04	0.967
Asking Question + Informing	-0.79 (-3.58, 1.99)	-0.56	0.574
Guiding	0.29 (-0.74, 1.33)	0.56	0.575
Cognitive Flexibility	0.19 (0.12, 0.26)	5.63	<0.0001
Achievement	0.38 (0.27, 0.48)	7.11	<0.0001

The results revealed that informing in the first period, CF, and AA positively predicted CR. The highest impact among these were providing additional information. When the level of informing, CF and AA increased, the level of successful CR also increased. In the second period, the results of the analysis showed that responding, ignoring, reminding, suggesting, guiding, cognitive flexibility, achievement predicted CR. On the other hand, responding, ignoring, reminding, suggesting and guiding negatively affected CR. When these variables increased, the level of successful CR declined. However, as CF and achievement increased, successful CR increased as well. The analysis results for the third period showed that only CF and achievement predicted the quality of CR.

Conclusion and Discussion

Our study was conducted to analyze the impact of social interaction among intern physicians during teamwork, their cognitive flexibility (CF) and academic achievement (AA) levels on successful clinical reasoning (CR). To our knowledge, ours is the first study in medical education discussing how students' CF and AA level during teamwork affect CR skills. In addition, another result that made this study original was the finding that not the quantity but the quality of the discourses in the team is important for successful CR. According to the first symptoms and findings about the case in the first period (when the uncertainty was high), informing each other in the team brought success in CR. Making more suggestions and confirming may have prevented the team from focusing on the case. Although guiding in the first period was not very significantly effective, over guiding in the second period played a negative role in CR. Because the second period (with additional information, decreasing uncertainty level) was the period of questioning, inquiry and judging preliminary diagnoses. Therefore, ignoring, reminding, and suggesting in the second period may have caused negative impact on CR. In the second period, the team discussed the preliminary diagnoses first, and focused on which preliminary diagnosis was weakened and strengthened while trying to reach a diagnosis through additional symptoms and findings. The team that wrote the reasons for the strengthening or weakening of the preliminary diagnosis and focused on discussing the findings instead of making new suggestions.

AA and CF in each period had a positive impact on a successful CR. Especially the third period was the one during which adequate level of discussion was made about the case and information saturation was reached. Therefore, the team needed to reach the final diagnosis and evaluate the process. CF and AA enabled this period to result in success although on previous study (Fürstenberg et al., 2019) analyzing the impact of AA on CR in medical education showed that achievement level of the students had no effect on the quality of CR. However, our study showed some similar results with various studies regarding the positive impact of AA (Elvén, 2019; Groves et al., 2003; Kim & Ko, 2015; Kuiper & Pesut 2004) and of CF (Durning et al., 2015; Simmons, 2010) on CR. Similarly, our study results also correlate with the results of the previous studies (Benner et al., 1997; Boaden & Leaviss 2000; Shafaroodi et al., 2014; Smith et al., 2008) that examine the impact of teamwork on CR. However, CF is not a common variable that has been studied in context of clinical practice or CR, which also makes this study authentic.

Our study revealed that academic achievement (AA) and cognitive flexibility (CF) levels of the students in teamwork has a positive impact on the quality of clinical reasoning (CR). Moreover, it was concluded that, for successful CR, the quality of discourses in the team is more important than how many discourses are created during the discussions. Future research may focus on the teams in which students with high and low AA levels or high and low CF levels work together in the same team. In addition, how students with high CF or vice versa affect others in the team would be another piece of research to see the impact of these conditions on CR. Also, a similar type of research may be conducted in different clinics or by including other healthcare professionals in the teams of doctors. Because doctors are the members of a team as a healthcare professional and this team may not always consist solely of doctors in clinical settings.

Limitations and Future Research

This study had several limitations that should be noted. First, the sample size was small (20 intern physicians-5 members in 4 teams). Second, the case given to the intern physicians was related to emergency department only. However, the emergency department is one of the four departments (emergency, internal medicine, gynecology and pediatrics) in which intern physicians can encounter most cases/patients upon graduation. Third, the time allocated for the discussion of the case was limited to 30 minutes (3 periods, 10 minutes for each period).

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Ethical Consideration

This study was approved by Çanakkale Onsekiz Mart University Clinical Research Ethics Committee (No: KAEK-27/2019-E.1900170534). All participants of the study gave their written consent for participation.

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Appendix

Period 1 (10 minutes)

The woman is 64 years old and has severe shortness of breath!
Suna, who is 64 years old, set out to go to the shopping mall on foot at 14:30 after lunch. On the way, she felt a pain in her stomach, making her difficult to breathe. So, she had to stop walking. Then, she took the medicine she was given to use when she had heartburn and pain. Her pain did not still subside. She changed her mind and decided to go back home which is very close, and she went to bed. At 17 o'clock, the severity of her pain increased, spread to her back, and shortness of breath reappeared. Shortness of breath increased when lying down. When her shortness of breath increased, she called her husband and asked him to take her to the hospital. Her husband drove her wife, Suna, to Ayvacık State Hospital.

Please write down the possible preliminary diagnoses for this patient, the reasons leading you to this diagnosis, and anamnesis, physical examination and examination information that can confirm this preliminary diagnosis and distinguish it from other diagnoses.

Expected Responses
In case the students write a complete response for preliminary diagnoses related to pneumonia, aortic dissection, myocardial infarction (MI), pulmonary edema, pericarditis, pericardial tamponade, pulmonary embolism, peptic ulcer, the reasons for these diagnoses, and anamnesis, physical examination and further examinations which is required for differential diagnosis, they can get 7x4=28 points from this section.

Period 2 (10 minutes)

Suna, who was brought to Ayvacık State Hospital by her husband, was welcomed by Dr. E. S. in the emergency service. The doctor took the patient's ECG and used PA Chest X-ray. Based on the examinations, Suna was diagnosed with pneumonia. The doctor sent the patient home by prescribing antibiotic and gastroprotective treatment.

On the following day, Suna was brought to ÇOMÜ Faculty of Medicine Emergency Department by her husband after her respiratory distress complaints increased and her pain became evident in the chest area. When the patient entered the emergency service, she was agitatedly shouting and asking for help, and constantly saying that she was afraid of dying. The patient could not lie on her back, was having difficulty breathing, breathing noisily, she had a cough, and was saying that she was expectorating.

In line with these new symptoms and findings, have your preliminary diagnoses changed? Which has become a priority? Why? Please write what you think and state your reasons in the table.

Expected Responses
With the new information given, if the students write that the probability of “Pneumonia”, which is one of the preliminary diagnoses that should be made in the previous period, didn’t change and the reason; the probability of “aortic dissection” increased and the reason; the probability of “MI” increased and the reason; the probability of “pulmonary edema” increased and the reason; the probability of “pericarditis” increased and the reason; the probability of “pericardial tamponade” increased and the reason; the probability of “pulmonary embolism” increased and the reason, the probability of “peptic ulcer” decreased and the reason, they can get 1 point for writing a correct answer for the probability (whether increased or decreased) and 1 point for writing the correct reason. So, they can get 7x2=14 points in total.

Period 3 (10 minutes)

Dr. T.E took the patient to the Emergency Service’s green zone at ÇÖMÜ Faculty of Medicine and examined her.

Patient History
Medical Record

diagnosed with hypertension 10 years ago.

diagnosed with diabetes mellitus 6 years ago
diagnosed with hyperlipidaemia 6 years ago
gastrointestinal system (GIS) bleeding 2 years ago

Medication

Oral antidiabetic, antihypertensive drugs, cholesterol medicine

Previous Surgical Operations

Caesarean

Family History

None

Physical Examination Findings

The skin is cold, pale, over-sweaty, moderate acrocyanosis.
Pulse: 110/min., rhythmic
Respiration: 26/min.
Fever: 36,6°C
Blood Pressure: 150/100
Widespread crepitant rales in both lungs up to upper zones during auscultation S3 present in the heart during auscultation
on the ECG taken in the emergency service:
Sinus rhythm
7mm R waves in V1, 1 mm S wave, 1 mm ST depression, Spiked T wave
R dominance in V2.
On chest X-ray:
The heart is larger than normal, aeration disorder suggesting bilateral pneumonic infiltration

In accordance with these findings, what is/are your final diagnosis/diagnoses for the patient, explain why? What do you think of the management of the patient's diagnostic process? Are there any problems you have noticed? What would your suggestions be for better management of this process?

Expected Responses
"Posterior MI" and "pulmonary edema" should be written as final diagnoses. If two answers are written, 4 points can be obtained from this section.

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A Systematic Review of Experimental Studies on STEM Education

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Abstract

This research systematically examines the experimental articles on STEM education (science, technology, engineering, and mathematics education). In this direction, experimental articles with the Social Sciences Citation Index on the Web of Science were analyzed within the scope of research questions, taking into account the guidelines of PRISMA. The research was carried out using the systematic review method. In the first search made in this line, the results listed 17,482 studies. Then, this number was reduced to 34 by applying the inclusion and exclusion criteria. Finally, the studies were examined in detail, and 12 articles that were not suitable were excluded from the scope. Thus, this research was carried out on 22 articles. In line with research problems, articles were categorized by publication year, country, method, study group and number, data collection tools, data analysis methods, topics covered, and experimental methods. The research results infer that the number of articles increases every year, and Turkey and China are the pioneering countries in this sense. It is noteworthy that mixed methods and quasi-experimental methods are generally preferred in the literature. Contrary to the literature, another result obtained from the research is that teachers are preferred in variable numbers as the study group. Scales, tests, and interviews are the most frequently used measurement tools by researchers. Besides, t-tests and content analysis are used in data analysis. Additionally, various topics are covered in the articles. One of the results obtained from the research is that the effect of STEM education on various skills and achievements is examined more. In line with these results, some suggestions were made by discussing the studies in the literature.

Introduction

Scientific and technological changes affect societies. Changes are inevitable as a result of this interaction. There is a need for a workforce that can use science and technology effectively for many countries that compete with one another (Kennedy & Odell, 2014). Countries that want to develop by adapting to this change make innovations and reforms in various fields to ensure that their workforce has the knowledge and skills required by age (Bybee, 2010). As a matter of fact, developing science and technology, decreasing energy resources, and global economic competition have changed the knowledge and skills that today's people must have (Roehrig et al., 2012). One of the key roles in acquiring this knowledge and skills is education.

Being a country that makes a difference in many fields today is possible with the 21st-century skills of the people of that country, such as critical thinking, innovation, cooperation, communication, problem-solving, creativity, and technology literacy (Partnership for 21st Century Learning [P21], 2015). One of the ambitious educational approaches to gaining these skills is STEM (science, technology, engineering, and mathematics) education (Bybee, 2010). STEM education is an innovative educational approach aimed at raising individuals equipped with the competencies of the age and ready for the world of the future (Güllü & Akçay, 2022). Today, STEM education is on the agenda of countries leading the world in many fields, and significant investments are being made (Banks & Barlex, 2014; Caprile et al., 2015; Corlu et al., 2014; So et al., 2018; US Department of Education, 2018).

The interest in STEM education in the world started in the 2000s and through the 2010s; however, it gained momentum and continued to increase (Yager & Brunkhorst, 2014). The importance of studies in the literature that report the general situation of studies on STEM education, which many researchers have been working on and which has a significant impact on education systems, is of great importance. There are studies conducted in this context in the literature (Arshad, 2021; Irwanto et al., 2022; Li et al., 2020; Martín-Páez et al., 2019; Matsuura & Nakamura, 2021; Wan et al., 2021). These studies are mainly carried out as traditional and systematic reviews. Hence, this study systematically examines the SSCI-indexed articles on STEM education.

Theoretical Framework

STEM Education

STEM education is an up-to-date approach that places students at the center from preschool to higher education, prioritizes collaborative learning, covers formal and informal education, emphasizes 21st-century skills, and ensures the realization of multidimensional learning by integrating science, technology, engineering, and mathematics disciplines. (Gonzalez & Kuenzi, 2012; Herschbach, 2011; Israel et al., 2013; Sainsbury, 2007; Smith & Karr-Kidwell, 2000). The main objective of STEM education is to educate individuals with the skills required by the age (Thomas, 2014). Although the aims of STEM education differ in various research and reports, they have some common goals. Some of those contribute to a country's economy by raising individuals with STEM literacy and those who can work in future business areas. STEM education also aims to keep a country's economy strong as well as skills and success (Deming & Noray, 2020; McGunagle & Zizka, 2020).

STEM education is an educational approach that encourages, motivates students, makes them achieve their dreams, has ethical values, can think systematically, and mediates them to transfer their knowledge and skills to different and new problem situations (Bybee, 2010; Dugger, 2010; Morrison, 2006). This allows STEM students to make plans, comments, and evaluations on ideas as well as solve the problems they encounter in daily life (Tseng et al., 2013). It is only possible for countries to achieve such developments with well-equipped individuals trained in STEM disciplines who are innovative and have science and technology literacy (Miaoulis, 2009).

Systematic Review

Systematic reviews are scientific studies in which the findings are analyzed by scanning the original scientific research on a particular subject in detail and using exclusion and inclusion criteria (Aslan, 2018). This concept is used as a *systematic review*, *systematic compilation*, *review*, and *literature review* in the literature. This research uses the "systematic review" term. Systematic reviews (Yılmaz, 2021), which are frequently encountered in studies in the field of health sciences (Medicine, nursing, etc.), are also used in fields such as business administration, psychology, sociology, educational sciences, and educational administration (Zawacki-Richter, 2020).

Karaçam (2013) suggests that review studies are in three different forms (Moule & Goodman, 2009; Gerrish & Lacey, 2010): (1) Traditional / narrative / literature / descriptive review, (2) Systematic review, (3) Meta-analysis. Yılmaz (2021) also states that systematic review and similar studies are basically content analysis studies. The most important guide to guide systematic reviews is PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). PRISMA has a detailed checklist and flow diagram for systematic review studies (Liberati et al., 2009).

Since certain criteria determine the studies to be used in systematic reviews, they are more objective than traditional reviews. Other researchers can repeat systematic reviews as they are carried out according to a certain protocol and have a clear method. However, this is not the case in traditional reviews, which prevents possible prejudices (Yılmaz, 2021).

Reviews on STEM Education

The literature on STEM education shows that there are traditional reviews (Brown, 2012; Hasanah, 2020; Martín-Páez et al., 2019; Mizell & Brown, 2017; Minichiello et al., 2018) and systematic reviews (Arshad et al., 2021; Ibáñez, & Delgado-Kloos, 2018; Irwanto et al., 2022; Jin, 2021; Kayan-Fadlelmula et al., 2022 Li et al., 2020) on this topic. There is also content analysis (Kaya & Ayar, 2020; London, 2018), meta-analysis (Jeong et al., 2019; Wang et al., 2022), and bibliometric analysis (Ha et al., 2020; Marín-Marín et al., 2021; Talan, 2021) studies.

The number of review and systematic review studies on STEM education in the international literature is gradually increasing. The widespread use of systematic review studies in educational sciences has attracted the attention of many researchers. In the literature, systematic review studies that deal with STEM education from various perspectives generally intensified in 2018 and beyond.

Systematic reviews of STEM education generally focus on augmented reality (Ibáñez & Delgado-Kloos, 2018; Yu et al., 2022), distance education (Alangari, 2022; Gamage et al., 2022), engineering design processes (Hafiz & Ayop, 2019), game-based learning (Gao et al., 2020), robotics (Ferrada-Ferrada et al., 2020; Hussin et al., 2019), special education (Ehsan et al., 2018; Kolne & Lindsay, 2020; Schreffler et al., 2019), computational thinking (Wang et al., 2021), mobile learning (Khaokhajorn et al., 2020), project-based learning (Imaduddin et al., 2021), measurement and evaluation (Mahanan et al., 2021), and artificial intelligence (Zawacki-Richter et al., 2019).

Some of the systematic review studies on STEM education are summarized below. Li et al. (2020) systematically analyzed 798 articles published in 36 journals between 2000 and 2018. (Gao et al. (2020)) systematically examined 30 articles between 2010 and 2019 within the scope of mobile game-based learning in STEM education. Wan et al. (2020) researched 24 experimental studies on STEM education in early childhood. Articles published in (Irwanto, 2022) and (Journal of Science Education and Technology, Research in Science Education, Journal of Science Teacher Education, International Journal of Science Education, Journal of Research in Science Teaching, and Science Education) journals were analyzed in another study. Arshad et al. (2021) systematically examined the remaining 17 articles after search strategies out of 1480 articles reached using Scopus, Wiley, and Google Scholar. Jin (2021) reviewed 24 experimental studies to support indigenous students in STEM education between 2011 and 2020. Ibáñez & Delgado-Kloos (2018) analyzed 28 articles they accessed using ERIC, Scopus, and Springer databases. Gamage (2022) used the 4-step PRISMA-P process to identify 155 eligible journal articles from 104 journals in 55 countries from 2015 to 2021.

Purpose of the Research

Experimental design is frequently used in studies on STEM education (Lin et al., 2019). To this end, reviews on STEM education are carried out with a general perspective (Arshad et al., 2021; Li et al., 2020). Considering the application dimension of STEM education, it is thought that the importance of experimental studies in this field is great. This research can accelerate researchers who want to conduct a meta-analysis. As a matter of fact, giving a general view of experimental studies facilitates the work of researchers. Studies in this direction in the literature are quite limited (Jin, 2021; Kalemkuş, 2019; Wan et al., 2020). Additionally, examining these studies in distinguished indexes such as WoS is significant in guiding current studies in this field. In this context, this research systematically examines the experimental studies on STEM education in the SSCI category on WoS. In this direction, the study seeks answers to the following research questions:

1. What is the distribution of studies on STEM education by year and country?
2. What are the methods and designs used in studies on STEM education?
3. What are the sample group and sample size in studies on STEM education?
4. What are the types of data collection tools and data analysis methods in studies on STEM education?
5. What are the trends in the topics covered in studies on STEM education and applied STEM activities?

Method

This research was carried out through the systematic review method. The systematic review method of the research was structured according to the PRISMA decision principles. With a checklist of over 20 items and a flow diagram, PRISMA principles ensure that literature review studies are carried out transparently (Liberati et al., 2009).

Search Strategy

All the data within the scope of the research were taken from the official website of the Web of Science (WoS). In the first search made with "Advanced Search," some keywords containing the research topic were used (Table 1).

Table 1. Search strategy

WoS Query	(TI=(STEM OR STEAM OR science, technology, engineering, and mathematics) AND TS=(EXPERIMENTAL OR PRE-TEST OR POST TEST))
Last Retrieved	13.08.2022

The last search was done on 13.08.2022. As a result of the search, 17,482 studies were reached. Research data were obtained from articles on this date. All articles that met the criteria determined by the expert opinions collected by the researcher were included in the research.

Database and Selection Criteria

WoS index is frequently preferred in meta-analysis, bibliometric analysis, and systematic reviews. The criteria for inclusion and exclusion of studies were formulated and applied to ensure that the included studies were closely related and of high reliability. The inclusion and exclusion criteria are shown in Table 2.

Table 2. Selection criteria

Inclusion Criteria	Exclusion Criteria
• Published in the WoS • Article • Written in the English • Open Access • Research areas: Education, Educational Research • WoS categories: Education, Educational Research • SSCI • Experimental method	• Not published in the WoS • Review article, book chapter / review, proceeding paper, etc. • Not written in the English • Descriptive, Correlational, Comparison, Historical method • Duplicate studies • ESCI, SCI-EXPANDED, CPCI-S, etc. • Research areas outside of education and WoS categories • Article unavailable in full text

The articles in the field of education, which were written in English with the SSCI index and adopted the open-access experimental method, were evaluated by taking them into the scope of the research. Unlike many studies, no year range was given in this study.

Publication Selection

PRISMA Flow Diagram was used to determine the studies within the scope of the research (Figure 1). Firstly, 17,482 studies were reached by using the search terms in Table 1. Then, studies that were not suitable were excluded using the inclusion and exclusion criteria (For example, the term STEM has a different meaning in the medical literature, types of studies other than the article, etc.).

Table 3. Filter strategies of articles

Category	Category
Access Type	Open Access
Document Type	Article
Research Area	Education Educational Research
Language	English
WoS Categories	Education Educational Research
WoS Index	SSCI
*https://www.webofscience.com/wos/woscc/summary/b3e501c0-4419-4bb1-81b8-e59439b7cdd6-4d5448da/relevance/1	

As a result of the filtering process in Table 3, the studies to be examined were collected in a folder. Then, it was checked whether there were repeated search results. At this stage, the number of articles decreased to 34. Then, data were collected through the "Article Classification Form," which was created to examine the articles easily. At this stage, 12 more articles that were not the focus of this research were excluded (due to scale development, use of STEM expression outside of education, etc.). Thus, the final number of articles to be analyzed in the systematic review was obtained (Appendix). The PRISMA Flow Diagram showing the process is shown in Figure 1.

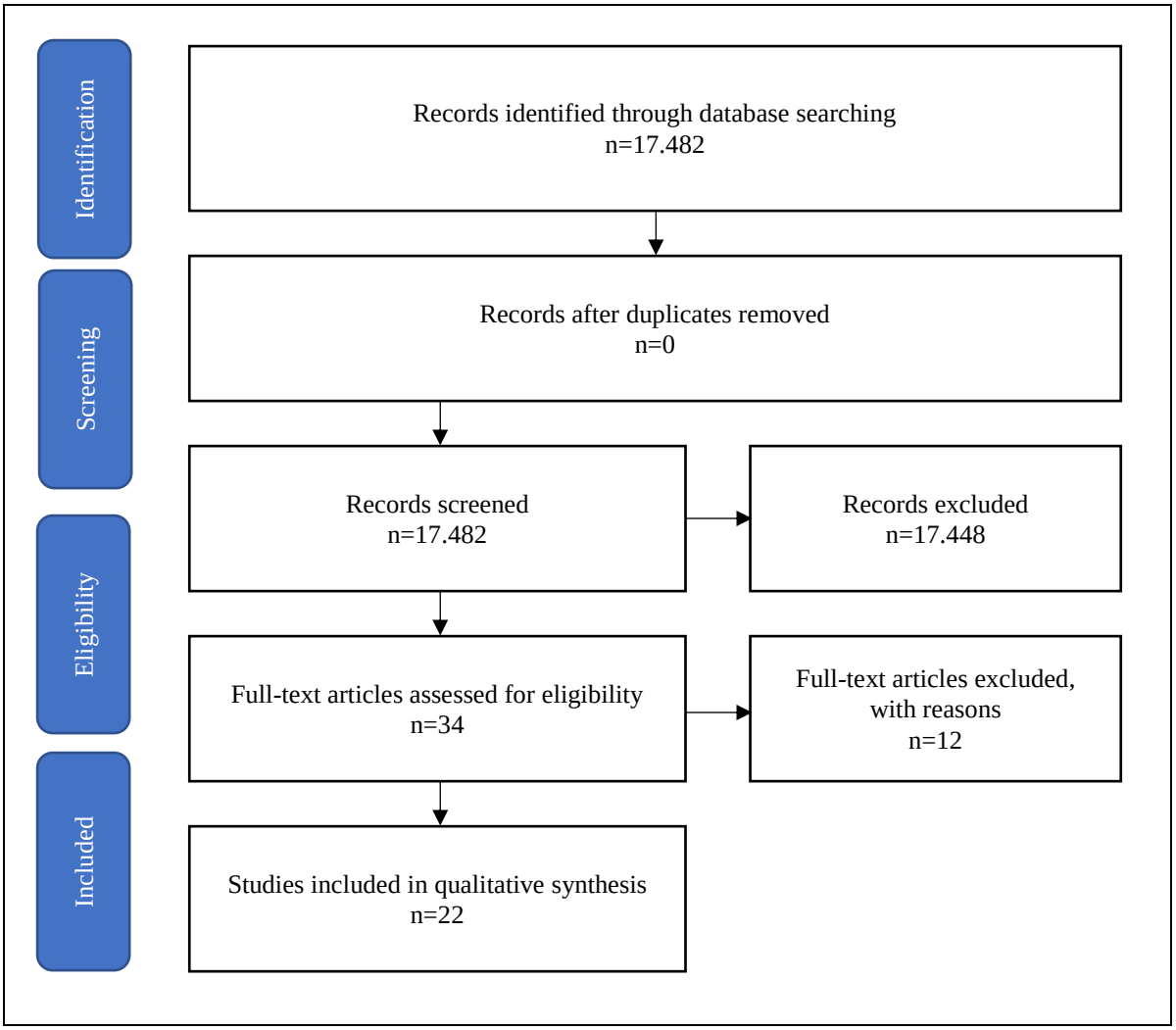


Figure 1. PRISMA flow diagram (Liberati et al., 2009)

Data Analysis and Coding

22 articles that were reached as a result of the literature review and that met the research criteria were examined (Appendix 1). An online article analysis table was created to avoid subjectivity during the analysis stage. Categories included in the table, excluding the article information: (1) Year of publication, (2) Method, (3) Experimental method, (4) Sample group, (5) Sample size, (6) Data collection tools, (7) Data analysis method, (8) Research topic, (9) Activity duration and number, and (10) Country. Findings are presented in tables and graphs with frequency and percentage values.

Validity and Reliability

For the validity of the research, a data search and filtering protocol was created during the data collection stage, where the search term can reach the studies suitable for the purpose of the research. Expert opinion was often used at this stage. Inclusion and exclusion criteria are clearly defined (54). Besides, the researcher explains each step of the process in detail.

The articles within the scope of the research were coded into the online article analysis table by another researcher who completed her Ph.D. Then, the percentage of agreement between the two codings was examined. The percentage of intercoder agreement was calculated as 98% (Miles & Huberman, 1994). This ratio shows an acceptable level of reliability.

Findings

Distribution of Studies by Year and Country

Figure 2 shows the distribution of the articles analyzed in line with the research problem by country.

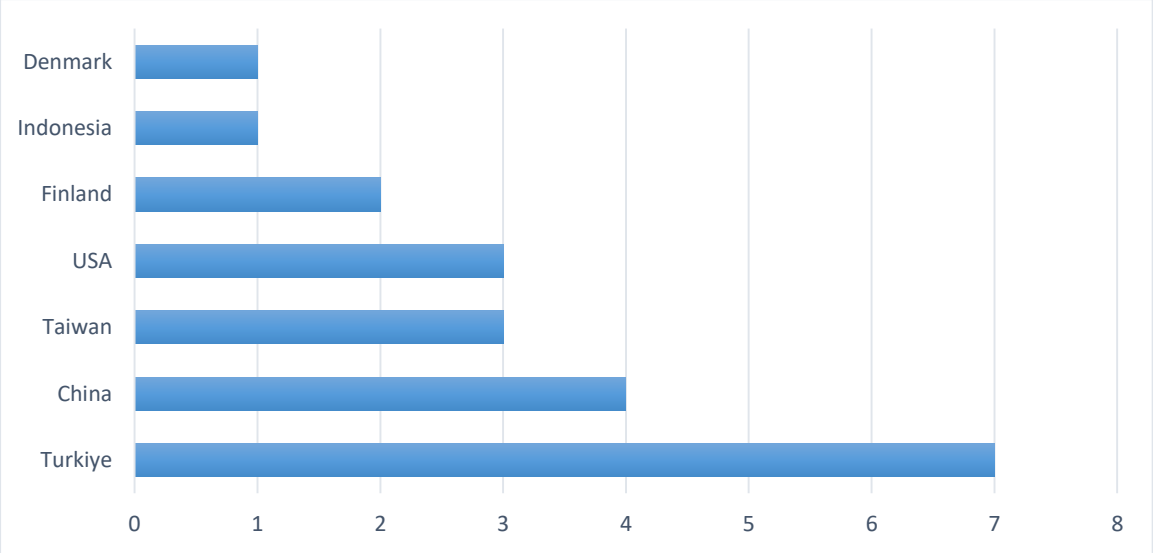


Figure 2. Distribution of articles by country

Figure 2 suggests that the articles were published in 7 different countries. Among these countries, most articles were conducted in Turkey (f=7) and China (f=4), followed by Taiwan, the USA, Finland, Indonesia, and Denmark.

The analysis results of the experimental articles covered in the research by year are shown in Figure 3.

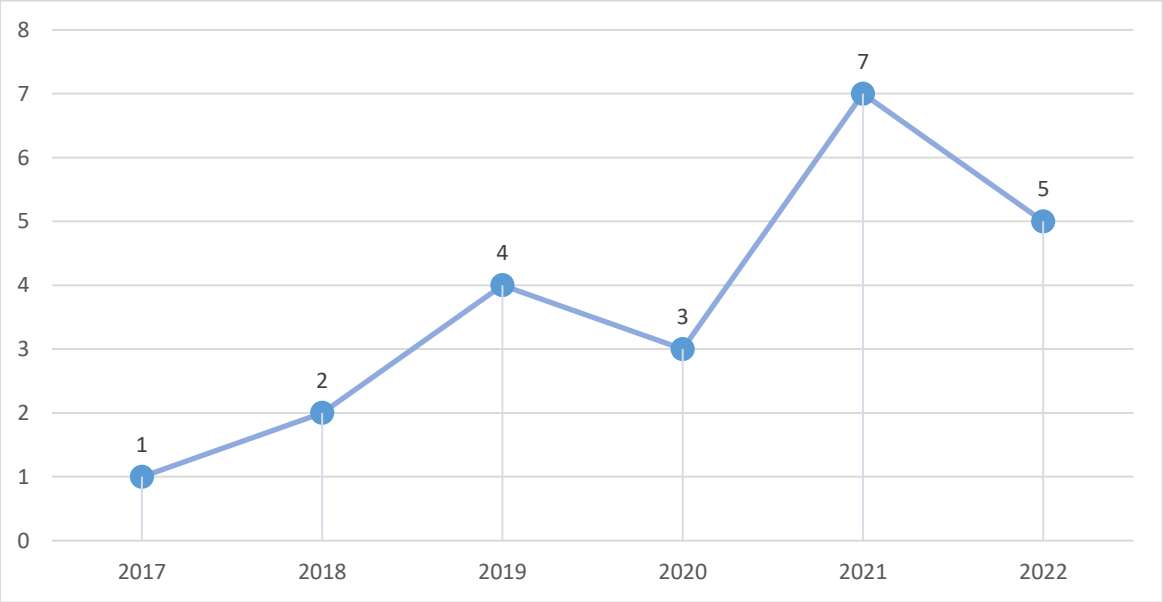


Figure 3. Distribution of articles by year

SSCI-indexed articles in this study were conducted between 2017 and 2022. Most articles were published in 2021 (f=7). Notably, four articles were published in 2019 and 2022. The articles generally tend to increase. However, there is a decrease only in 2020 and 2022 compared to the previous year.

Methods and Designs Used in Research

In line with the research's second sub-problem, the experimental articles' methods and designs were discussed (Figure 4).

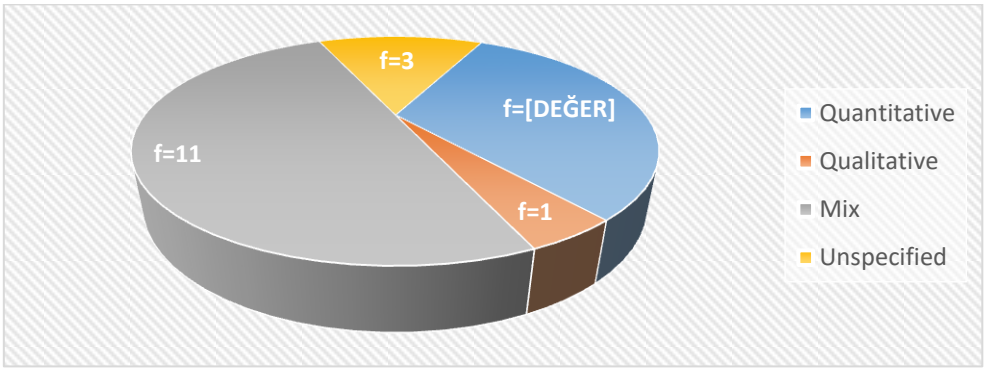


Figure 4. Distribution of articles by the methods used

As a result of the analysis, the experimental articles are generally conducted with a mixed method in which quantitative and qualitative methods are used together (f=11). While the number of articles using the quantitative method was 7, 1 article was designed with qualitative methods. In the remaining three articles, no clear information was given about the method used. When the articles are evaluated in terms of the experimental design they use, a total of 11 articles clearly indicate that they use the experimental design. No information was given about the experimental design used in the remaining articles. While the quasi-experimental design is used in 9 of the articles, the weak-experimental design is used in 2 articles.

Sample Group and Sample Size of Articles

Sample groups of experimental articles examined in the context of STEM education were examined. Descriptive data for these groups are shown in Figure 5.

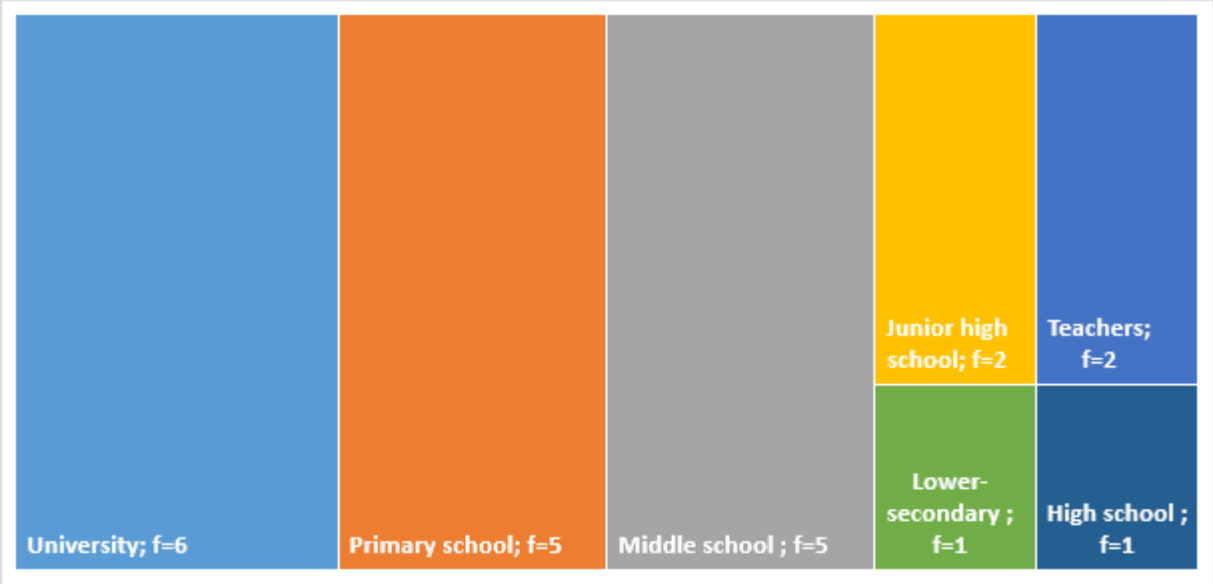
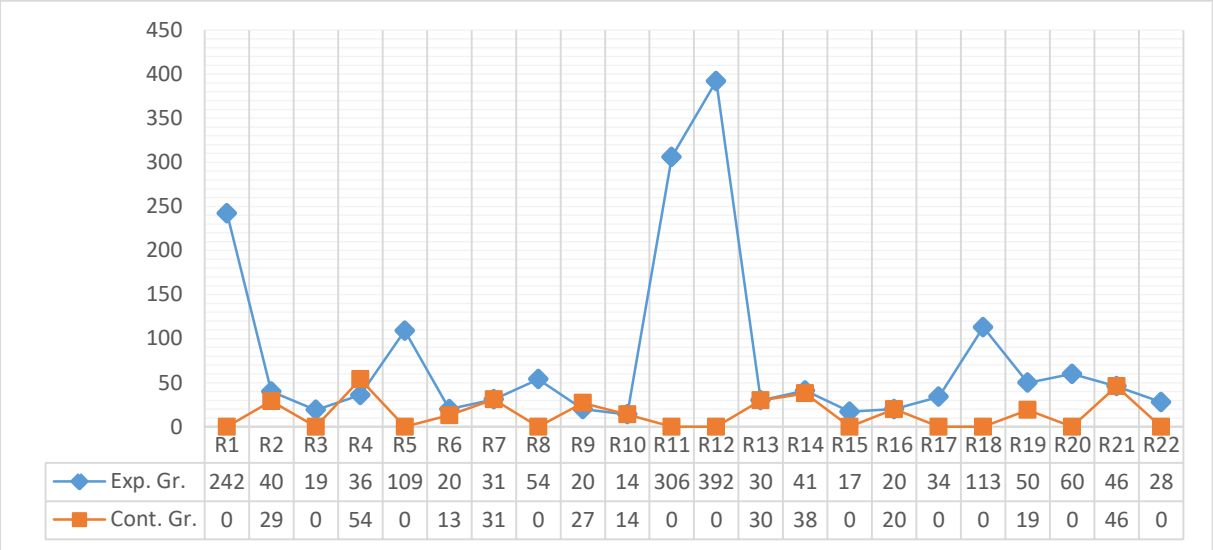


Figure 5. Distribution of articles by the sample group

Figure 5 reflects that university students are the sample group most in the experimental articles on STEM education (f=6). 2 of these 6 articles were conducted with prospective teachers, followed by primary school students (f=5) and middle school students (f=5) sample groups, respectively.

The number of participants in the experimental and control groups of the experimental articles was also analyzed. Figure 6 shows the number of participants in the experimental and control groups.



	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
Exp. Gr.	242	40	19	36	109	20	31	54	20	14	306	392	30	41	17	20	34	113	50	60	46	28
Cont. Gr.	0	29	0	54	0	13	31	0	27	14	0	0	30	38	0	20	0	0	19	0	46	0

Figure 6. Distribution of the number of participants in the experimental and control groups

Figure 6 points out that half of the articles (f=11) were carried out by including control groups. This means that at least two different groups represent the sample of these articles. The experimental groups consisted of at least 14 and at most 382 people. This is a remarkable finding, given that experimental articles are usually carried out in small groups. In the control groups, the number consists of at least 14 and at most 54 people.

Data Collection Tool and Data Analysis Techniques of Articles

The findings regarding the data collection tools used in the SSCI-indexed experimental articles on STEM education are shown in Figure 7. A total of 57 data collection tools, 36 of which were quantitative and 17 were qualitative, were used in the articles.

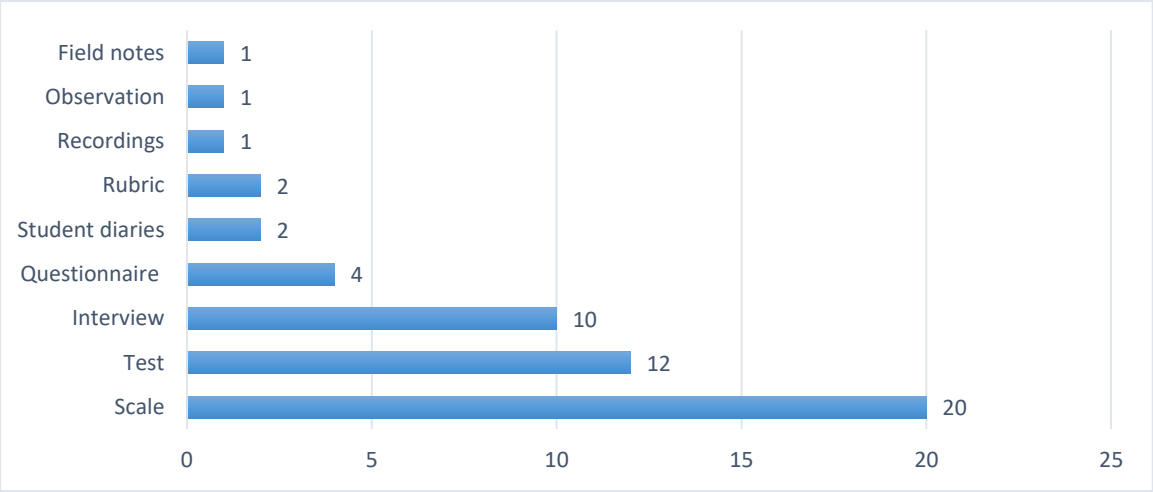


Figure 7. Distribution of data collection tools used in articles

Figure 7 reveals that scale, test, and interview are generally used as data collection tools. Creativity and skills (f=4), attitude (f=3), motivation (f=3), and career interest (f=3) scales are frequently used. In addition to these, self-efficacy (f=2), literacy (f=1), and computational thinking (f=1) are other scales used in research. However, not as much as scales, tests (f=12) and interviews (f=10) are frequently used in experimental articles. Considering the tests, it is among the findings obtained from the research that the achievement (f=6) and knowledge (f=3) tests were used the most. Besides, creativity (f=1) and problem-solving (f=1) tests are also used, albeit not very often. Another measurement tool that is frequently used in experimental articles within the scope of the research is interviews (f=10). Almost all the interviewed articles were conducted with semi-

structured interviews (f=8). In some articles, structured interviews and focus group interviews were used. Other data collection tools used in the articles are questionnaires (f=4), diaries (f=2), and rubrics (f=2).

The analysis methods used by the experimental articles were examined under two headings as qualitative and quantitative (Figure 8).

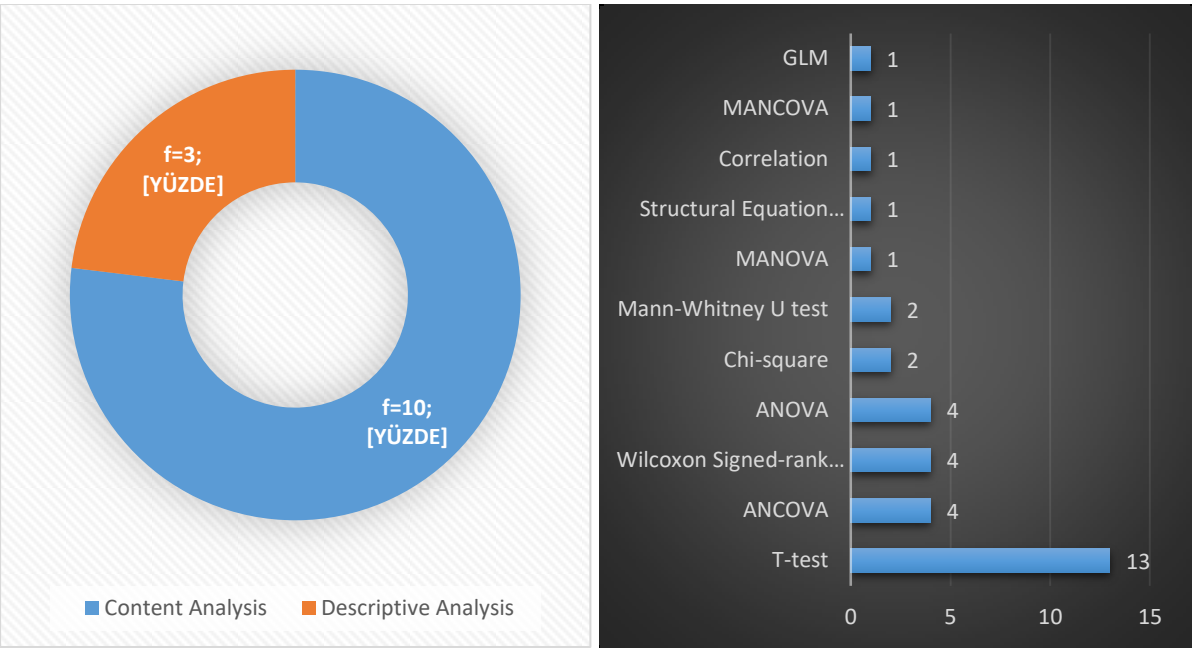


Figure 8. Distribution of qualitative and quantitative analysis methods used in articles

Content analysis (f=10) is used more than descriptive analysis (f=3) in the qualitative dimensions of experimental articles. In one of the articles, both content analysis and descriptive analysis were used together. In the quantitative analysis methods used in the articles, the number of t-tests (f=13) is more than the others, followed by ANCOVA (f=4), Wilcoxon Signed-rank Test (f=4), ANOVA (f=4), Chi-Square (f=2), and Mann-Whitney U Test (f=2).

Topic and Application Process of Articles

The topics on which the effect of STEM education was investigated in the experimental articles analyzed within the scope of the research are shown in Table 5. In some articles, more than one topic is examined.

Table 5. Topics examining the effect of STEM education in the articles

Subject	f	%	Subject	f	%
Skills	5	11.26	Professional development	1	2.32
Achievement	4	9.30	Gender	1	2.32
Attitude	3	6.97	Autonomy	1	2.32
Learning	3	6.97	Visual reasoning	1	2.32
Creativity	3	6.97	Abstract thinking	1	2.32
Career interest	3	6.97	Self-explanation	1	2.32
Self-efficacy	2	4.65	Cognitive load	1	2.32
Project-based learning	2	4.65	Conceptual understanding	1	2.32
Motivation	2	4.65	Computational thinking	1	2.32
Cognitive learning	2	4.65	Task value	1	2.32
Flow experience	1	2.32	Socio-scientific issue-based instruction	1	2.32
Opinion	1	2.32			
Total				43	100

Table 5 indicates that the experimental articles deal with quite wide and different topics. To this end, 24 different topics were examined by researchers in 22 experimental articles. Experimental articles are mostly

focused on skills (f=5), achievement (f=4), attitude (f=3;), learning (f=3), creativity (f=3), and professional interest (f=3).

The word cloud consisting of the titles of all the articles within the scope of the research is shown in Figure 9. Conjunctions and meaningless expressions were excluded while creating the word cloud. In this sense, the concepts of STEM, effect, and learning are prioritized in the word cloud.

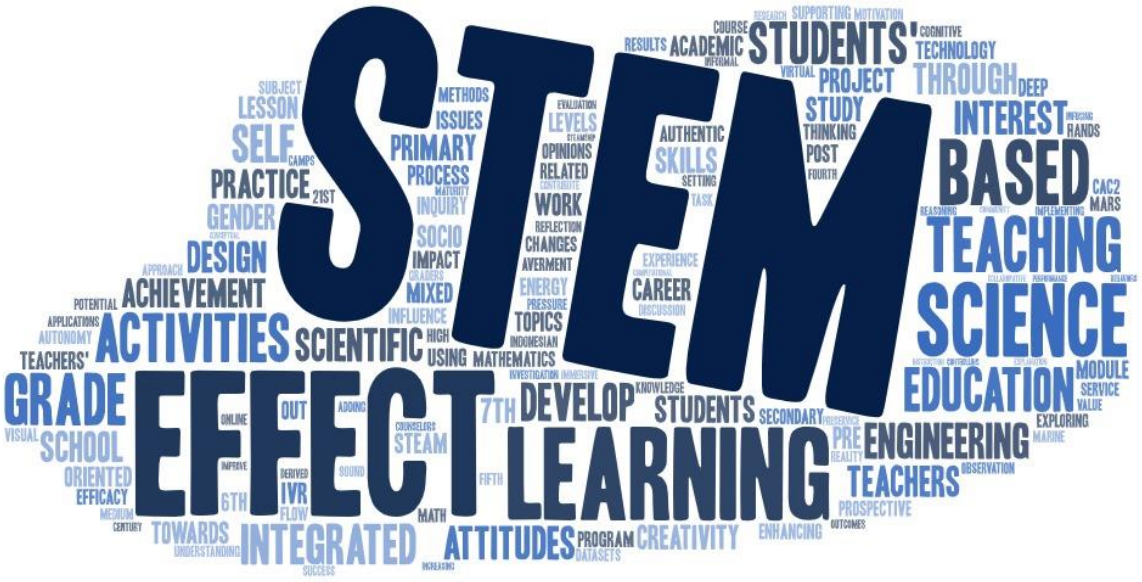
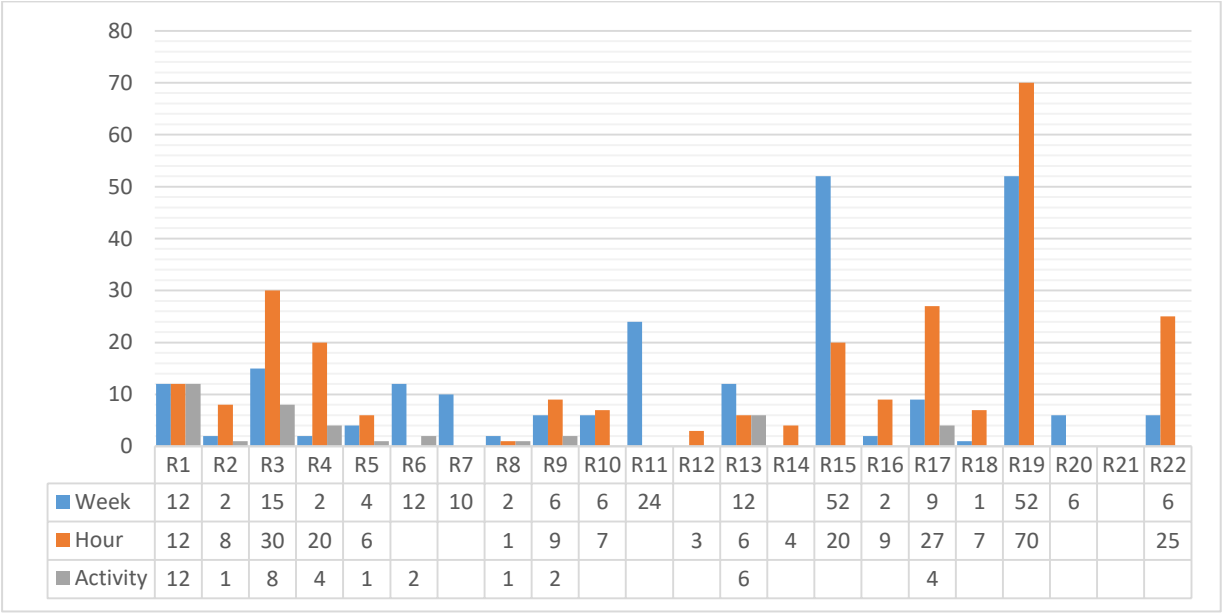


Figure 9. Word cloud of titles of experimental articles

The articles conducted on STEM education and the distribution of the experimental application processes of these articles are shown in Figure 10. The figure gives information about how many weeks the application covers, how many hours it is completed, and the number of activities implemented. If there is no information about the application in the article, the relevant fields are left blank.



	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22
Week	12	2	15	2	4	12	10	2	6	6	24		12		52	2	9	1	52	6		6
Hour	12	8	30	20	6			1	9	7		3	6	4	20	9	27	7	70			25
Activity	12	1	8	4	1	2		1	2				6				4					

Figure 10. Distribution of the experimental application process in the context of week, hour, and activity

Figure 10 shows that STEM activities within the scope of experimental articles are carried out between 1 and 52 weeks. There are three articles that do not provide information on how many weeks STEM activities last. Time information is provided for activities in two of these articles. Additionally, the activities are carried out between 1 and 70 hours. In total, five articles did not provide information about the time allocated for the activities.

Besides, there are 1 to 12 STEM activities in the experimental articles within the scope of the research. The number of studies without information about the number of STEM activities applied is 12.

Discussion

As a result of the use of systematic review studies in education fields, the number of systematic review studies on various perspectives of STEM education has rapidly increased. Systematic reviews are important in giving a general idea about the researched area. As a matter of fact, through systematic reviews, topics that need to be researched in the future, gaps, and insufficient areas in the literature can be identified (Çınar, 2021). In this research, a systematic review of experimental articles on STEM education on WoS was made. Thus, a profile of experimental articles for STEM education is thought to be created.

When evaluated in terms of countries, the experimental articles in Turkey and China are notable, which can be explained by the high interest in STEM education in these two. Thus, there are many initiatives for STEM education in Turkey (Integrated Teaching Project, Scientix Project, etc.). This also signifies that qualified researchers are producing quality publications on STEM education in these countries. There are studies in the literature that infer different results (Sawangmek, 2019; Talan, 2021). It is significant that in some of these studies, the USA is in the leadership position (Le Thi Thu et al., 2021; Marín-Marín et al., 2021; Yu et al., 2016). Indeed, the USA is far ahead in the Wilson et al. (2022) study. In another study, South Korea, the USA, and Indonesia were the most productive countries (Santi et al., 2020). The contrast encountered here is thought to be related to the keyword, search strategies, and database used.

Experimental articles on STEM education generally tend to increase. It was concluded that there was a decrease only in 2020 and 2022 compared to the previous year. Since this research was carried out in 2022, the studies in 2022 are expected to be lower than in the previous year. A similar finding was obtained by Talan (2021). Many studies in the literature also show a similar trend (Ha et al., 2020; Li et al., 2019; Marín-Marín et al., 2021; Wilson et al., 2022; Yu et al., 2016). Irwanto et al. (2022) reported that the number of articles between 2011 and 2020 is in regular increase. Chomphuphra et al. (2019) also have similar results.

The studies examined within the scope of the research mainly use mixed research methods. The main reason for combining quantitative and qualitative methods in mixed methods is to reveal their strengths by compensating for the weaknesses of both approaches (Merriam, 2013). According to Kurniati et al. (2022) concluded that the qualitative method is preferred in studies on STEM education. Irwanto et al. (2022), on the other hand, found that the quantitative method was used more frequently. The emergence of different results is thought to be a result of search strategies. Besides, Kalemkus (2019) concluded that the experimental research on STEM education that he examined used the mixed method more often.

This research proposes that university students are frequently involved as participants in experimental articles. Additionally, experimental articles are conducted with an average of 20 to 40 people. In contrast to this research, Kalemkus (2019) found that studies on STEM education are generally conducted with secondary school students. There are studies in the literature showing that studies on STEM education are frequently carried out at the level of K-12 (Mizell & Brown, 2016), graduates (Jayarah et al., 2014), preschool (Sawangmek, 2019), high school (Farwati et al., 2021), and middle school (Gao et al., 2020). This difference can be explained by conducting the relevant study on a national scale. According to Çavaş et al. (2020), university students are preferred more than other groups. University students often take part in scientific research as a study group, which can be explained by the desire of researchers to access data quickly and easily.
Scales and tests are prominent as data collection tools in experimental articles. They are frequently used in experimental studies. This case can be explained as a result of the design of the studies with a mixed method. Having conducted a study on STEM education trends in Turkey, Çavaş et al. (2020) have reached a similar conclusion. A similar conclusion was also obtained in another study examining studies on augmented reality in STEM education (Sırakaya & Alsancak Sırakaya (2022). Some studies show that the interview is more prominent (Wilson et al., 2022). When experimental articles are analyzed in terms of data analysis, qualitative data are analyzed using content analysis, and quantitative data are generally analyzed using a t-test. There are studies with similar results in the literature (Çavaş et al., 2020; Gül et al., 2022).

As a result of the research, the experimental articles mostly focus on subjects such as skills, success, attitude, learning, creativity, and professional interest. When the titles of the examined articles are transformed into a word cloud, the concepts of “STEM,” “effect,” and “learning” are the most repeated ones. The reason for this can be explained by the nature of experimental studies, covering the effect of something on something and the

topic area. This finding is supported by similar results in the literature (Aseffa & Rorissa, 2013; Novia et al., 2021; Tas & Bolat, 2022; Wilson et al., 2022; Yu et al., 2016). Gülhan (2022), on the other hand, stated that the most examined variables are attitudes and skills.

It is seen that the implementation processes of the experimental articles examined within the scope of the research last up to 52 weeks, and some activities total 70 hours. The number of activities was found to be at most 12. Günbatar and Tabar (2019) report that STEM activities last 1-2 months in their studies. Kalemkuş (2019), on the other hand, noted that STEM activities were carried out intensively between 6 and 10 weeks. Sufficient time and the number of activities for STEM education may vary in line with the content of the subject and the knowledge and skills targeted to be gained. For example, an experimental process that aims to determine the effect of STEM activities on attitudes needs to be designed comprehensively.

Conclusion

Although there are systematic review studies on STEM education in the literature, studies examining experimental studies are limited. The current studies cover certain education periods. In this research, experimental articles with SSCI on STEM education were examined. As a result of the research, which examines the experimental articles on STEM education, the countries with the highest number of articles are Turkey and China. One of the research results is that the number of experimental articles regularly increase yearly, and most articles were published in 2021. In experimental articles, mixed method design was most preferred. It was noted that some articles did not provide any information about the method. Another result of the research is that the study group usually consists of university students. One of the research results is that half of the experimental studies were designed with a control group. It is indicated that scale, test, and interview are frequently used as data collection tools. Due to the intensive use of mixed methods in the research, data analyzes were collected in two groups. Content analysis in qualitative data analysis and t-test in quantitative data analysis are the most preferred analysis methods. Another result is that the researchers covered subjects such as skills, achievement, and attitudes towards STEM education more. It is seen that experimental applications are carried out with an average of 1 to 10 weeks and 1 to 10 activities. Besides, it was observed that many articles did not explain the implementation process in detail.

Recommendations

The number of systematic review studies on STEM education can be further increased. Investigations can be made on the sample of countries. Studies with experimental and control groups, which have an important place in experimental studies, can be carried out more. Studies can be conducted with more than one experimental and control group. Studies can be conducted on how long and with how many activities the skills of STEM applications, such as problem-solving and scientific creativity, can be learned.

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Studies on Robotic Coding Education in Science Education: A Systematic Literature Review

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Abstract

This study aims to examine the methodological trends and findings in studies on robotic coding in science education published between 2015-2022 comprehensively and holistically. For this purpose, the articles related to the subject were systematically reviewed. In addition, web of Science and SCOPUS databases were scanned for keywords related to robotic coding, and 15 studies on robotic coding with full-text access were included in the analysis. The researchers prepared a data collection form to analyze the publications included in the research within the framework of the determined categories. Regarding the results of the review of robotic coding studies in science education, they mainly focus on cognitive skills, followed by applied studies in robotic coding teaching. The suggestions for future robotic coding studies in science education mainly involve applications and further research. Regarding applications, there are more suggestions for the integration of robotic coding. In this context, it was recommended to carry out studies that examine various 21st-century skills, integrate different disciplines, use different equipment, address psychomotor skills, and focus on curriculum development.

Introduction

The widespread use of technology in the world has led to developments in many areas. For example, communication technologies such as tablets, phones, and computers are widely used in homes, workplaces, schools, and social life. Computers used in workplaces, robot vacuums used at home, and self-parking vehicles are examples of technologies used in daily life.

Individuals of the 21st century have access to vast amounts of information and live in a technology- and media-driven environment. For this reason, there is a need for the use of technology in education and the integration of innovative, developing, and widely used technologies into lessons. For example, augmented reality, virtual reality, mixed reality, mobile applications, simulation, social networks (Facebook, Instagram, etc.), educational and digital games, digital storytelling, artificial intelligence, QR code applications, and 3D printing (Adams Becker et al. 2016; Johnson et al., 2015), metaverse and robotic technologies are developing technologies that are frequently used in education.

New educational approaches and models have emerged with the increasing use of technology in education. One of these models is robotic coding, which is on the agenda as a sub-dimension of STEM (Science, Technology, Engineering, and Mathematics) (Reader, 2019). Parents and educators have recently started to concentrate on the missing "T" of technology and the "E" of engineering in STEM programs thanks to the development of new technologies, curricula, and national efforts (Bers et al., 2013). Therefore, it can be said that providing robotics and coding training with a STEM approach will make it easier to reach 21st-century skills.

Individuals need 21st-century skills to adapt to the changing world. However, different institutions, organizations, and authors classify 21st-century skills differently (Partnership for 21st Century Skills[P21], 2010; Trilling & Fadel, 2012; Wagner, 2008). For example, P21 classifies 21st-century skills as learning and innovation skills, career and life skills, and information, media, and technology skills. Trilling & Fadel (2012) address 21st-century skills in three sub-titles: learning and innovation, digital literacy, and career and life skills. Wagner (2008), on the other hand, discusses 21st-century skills under seven headings, taking the initiative, entrepreneurship, adaptability, leadership, cooperation, problem-solving, critical thinking, imagination, access to information, and communication. These skills overlap with the skills required for coding (technology literacy, communication, problem-solving, scientific creativity, cognitive process skills, etc.).

The concepts of coding and programming began to be used in education in the 1960s. As a result, coding and programming are used interchangeably in the sources. However, it should be noted that programming is a broad concept that includes coding. Moreover, the interest in coding, which has emerged as a requirement of the digital world, is increasing. In general, coding emerges as describing the tasks we want a computer, machine, or system to do in an appropriate language. Coding is the entirety or a portion of a series of instructions written for a computer, electronic circuit, or mechanical device to carry out an action or accomplish a certain goal (Guven et al., 2022). In other words, coding is writing a block-based computer program by setting up various algorithms using a software language (Reader, 2019). Coding can be done with or without a computer. In computerized coding, tablets and smartphones can be used instead of computers.

Garcia-Pealvo et al. (2016) claim that teaching kids how to code enhances their capacity to use technology, helps them learn, and gets them ready for a variety of life situations. The ability to code is acknowledged as being vital for the growth of computational thinking, teamwork, communication, and creative problem-solving skills (Bocconi et al., 2016). Bers (2008) sees coding as a way to achieve literacy in the 21st century, just like reading and writing.

Although the discussions about coding started in the USA, they have rapidly spread to other countries (Aydeniz & Bilican, 2018). Coding education did not stay only at the K12 level (preschool, primary and secondary education) but also took place in undergraduate and graduate education. Many countries (USA, Australia, Brazil, Europe, etc.) have included coding education in their curriculum to improve children's computer programming and coding skills (Aydeniz & Bilican, 2018). Coding education efforts took place nationally and locally in these countries (USA, Australia, Brazil, Europe, etc.). In Turkey, the Ministry of National Education has decided to gradually add a course called "Information Technologies and Software" to the curriculum starting from the fifth grade in the 2012-2013 academic year (Sayın & Seferoğlu 2016). There are different organizations and different practices related to coding. Organizations such as Code Academy, Code Club, Khan Academy, Coder Dojo, and Code.org continue their efforts to teach coding in the programming field. Programming tools such as Microsoft Small Basic, Alice, MIT App Inventor, and Scratch are also available for individuals who have just started programming (Demirer & Sak, 2016).

Another concept that comes up with coding is robotics. Robots are functional tools that can be programmed to perform a task. Robots can sense the environment through sensors; the data obtained from sensors are interpreted, and various reactions are produced as programmed by the microcontroller or processor (Guven et al., 2022). Robots are controllable and programmable technological devices with sensors consisting of electronic and mechanical parts (Arora, 2008). The use of robots has become widespread not only in engineering but also in education (Yolcu & Demirer, 2017; Papert, 1980). On the other hand, robotic coding is defined as block-based programming to control and direct the movements of a robot created for various purposes (Reader, 2019).

The number of studies (articles, web pages, and various materials) on using robots in education is increasing. The studies on the educational use of robots stated that robots contribute positively to students' problem-solving skills (Robinson, 2005; Rogers & Portsmore, 2004). In addition, educational robotics applications attract the attention of students (Prensky, 2008), increase their learning motivation (Bazylev et al., 2014; Robinson, 2005; Rogers & Portsmore, 2004), improve their self-efficacy (Psycharis & Kallia, 2017), creative, critical, computational thinking skills (Catlin, 2012; Czerkawski & Lyman, 2015) and contribute positively to their learning in cognitive, affective, social and moral development areas (Lau & Yuen, 2011; Wei et al., 2011).

By combining robots and cutting-edge technological applications in the classroom, the studies in the subject of robotics education seek to give teachers a robotics curriculum that is connected with science and technology and to make learning more significant and lasting (Wood, 2003). The widespread interest in robotics has grown surprisingly over the past few years. Robotics is seen by many as a means of providing critical new benefits at all levels of education (Johnson, 2003). Robots used in education seem to be suitable tools to improve learning. However, more empirical studies are needed to test their benefit (Benitti, 2012).

The WOS database was used for the systematic review of coding education in science education. The database was scanned using robotic coding and systematic analysis as keywords, and 18 studies have been found. However, only four of these studies were conducted in the field of education (Ezeamuzie, 2022; Sun & Zhou, 2022; Taslibeyaz, 2020; Wang et al., 2021). Furthermore, one of these studies was a meta-analysis (Sun & Zhou, 2022). This situation shows a need for more systematic reviews on coding education in science education. This study is important because it synthesizes the studies conducted between 2015-2022 on robotic coding education in science education.

This study is valuable for determining the trends in robotic coding education in science education. It aims to determine the trends of the studies conducted between 2015-2022 on robotic coding in science education. In addition, this study interprets and outlines research on robotic coding in science education.

Method

This study was designed as a systematic literature review (SLR) on robotic coding in science education. The systematic review is a method mainly developed to synthesize research findings in medicine systematically, transparently, and reproducibly (Davis et al., 2014).

A systematic review can be described as a research method and process for collecting and analyzing data from research and identifying and critically evaluating the relevant ones (Liberati et al., 2009). It aims to reveal all empirical evidence that meets predetermined inclusion criteria to answer a particular research question or test a hypothesis (Snyder, 2019). Examining the articles and all available evidence through clear and systematic methods provides reliable findings by minimizing bias (Moher et al., 2009).

Literature review studies are divided into three; formal review (traditional, narrative review), systematic review, and meta-analysis (Petticrew & Roberts, 2006). A systematic review consists of three stages: planning, execution, reporting & generalization (Tranfield et al., 2003). This study systematically examined the literature on robotic coding in science education, following the five steps suggested by Petticrew and Roberts (2006). These steps are; Formulating the research question(s), defining inclusion/exclusion criteria, recording relevant studies systematically, evaluating the quality of selected studies, integrating major findings. In other systematic literature review studies, same procedures have also been employed (Ozsen, 2022; Uslu, 2020).

Research Questions

This study aims to conduct a literature review on the use of robotic coding in science education for the following purposes:
(a) presenting a synthesis of the empirical evidence available so far on robotic coding in science education
(b) submitting suggestions for future studies on robotic coding in science education based on the reviewed literature

Inclusion-Exclusion Criteria

A systematic search begins by defining the scope, keywords, and search terms generated from the literature and discussions within the review team (Tranfield et al., 2003). In this study, the researcher first defined the criteria before starting the systematic research protocol to select studies related to robotic coding education.

Inclusion	Exclusion
+ listed in certain indexes (Web of Knowledge and SCOPUS) + relevance to robotic coding education (in science education) + published after 2015 + written in English + a peer-reviewed article + empirical research	- country-specific indexes (e.g., Australian Education Index, British Education Index, etc.) - irrelevance to robotic coding education - published before 2015 - not in English - not a peer-reviewed article - not empirical research

Systematic Search Protocol

Studies were primarily identified through systematic searches made on relevant electronic databases. In the data collection process, WOS and Scopus databases were scanned for publications published between 2015-2022, with robotic coding education AND science education in their keywords, and 74 studies were listed. In the WOS database, 50 articles with the robotic coding education AND science education keywords in the title section were reached. In the Scopus database, 24 articles with the robotic coding education AND science education (limited to social science) keywords in the title section were found.

The search duration depended on the availability of access to electronic databases from the Eskisehir Osmangazi University library between June 2022 and August 2022.

Retrieved articles were examined in terms of title, abstract, and keywords, and studies on coding in science education were selected. The number of sources included and excluded at each review stage is documented, along with the reasons for exclusion (Tranfield et al., 2003). For example, 8 papers were not included in the study, because there were doubts about their reliability and the other 51 studies were excluded because there have not addressed coding in science education. As a result of the eliminations made according to the criteria, 15 articles suitable for this study were included (Figure 1). This study followed the PRISMA guideline, which provides an evidence-based framework and standards for conducting a systematic review. The PRISMA flowchart represents the key findings of the systematic analysis. The flowchart includes four stages: identification, screening, eligibility, and inclusion (Moher et al., 2009).

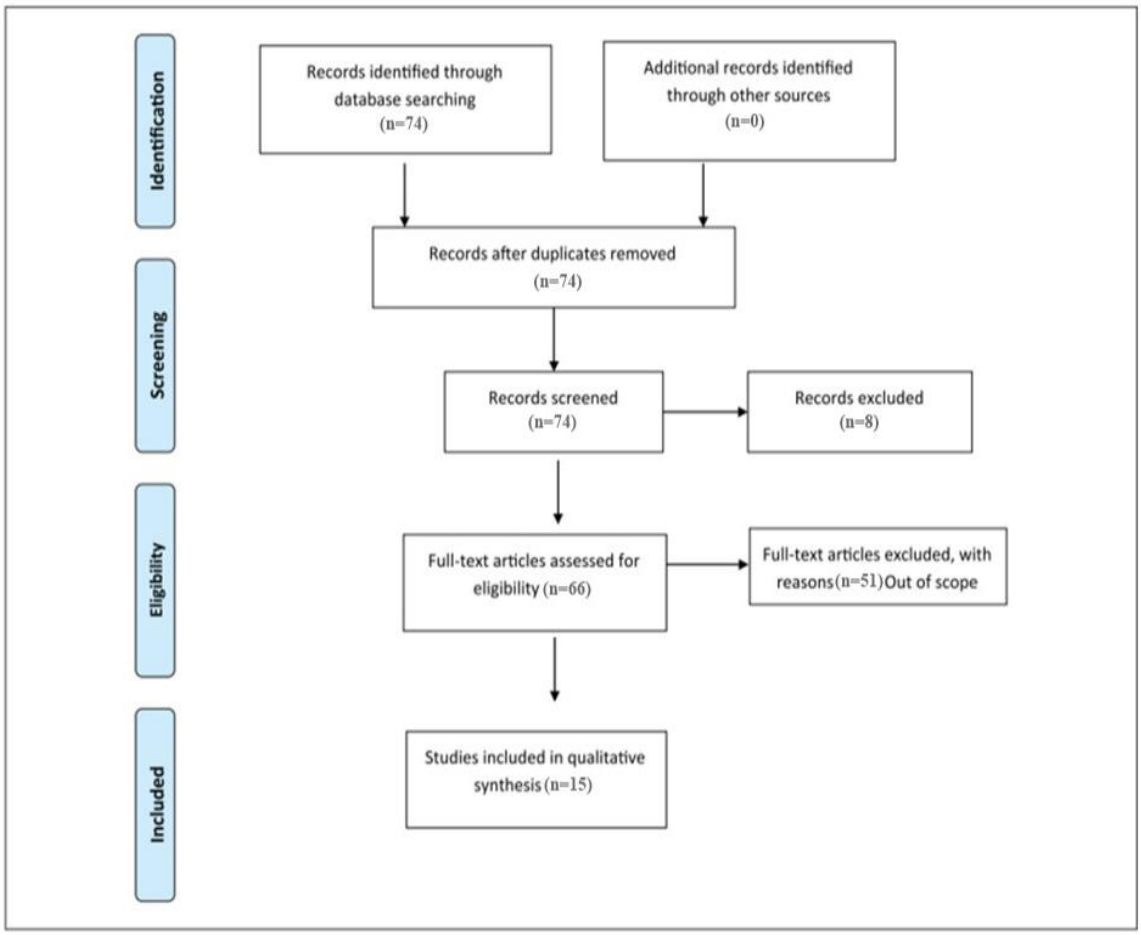

Figure 1. PRISMA Flowchart for the systematic review on "robotic coding education."

Quality Appraisal

The evaluation of the quality of qualitative research is quite controversial. There is little consensus on how to evaluate quality, who should evaluate it, and whether quality should be considered concerning "qualitative" research (Seale, 1999; Spencer et al., 2003). The quality of any systematic review or meta-synthesis depends on the quality of the works it contains. However, there is no definitive list of criteria for evaluating the quality of qualitative studies (Popay et al., 1998). The quality of qualitative research should be evaluated to avoid reaching unreliable conclusions (Thomas & Harden, 2008). All the studies selected in this review are articles published in peer-reviewed journals indexed in prestigious academic databases (WOS, SCOPUS). In addition, all selected articles consist of empirical research. Seven of these selected studies were full-text papers presented at congresses. They were excluded from the study because a consensus could not be reached on the quality of the full-text papers. Therefore, the entire methodology has been rigorously reviewed. First, a customized evaluation and data extraction form that utilizes primary research evaluation tools was developed. Individual studies in the

systematic review were evaluated according to predetermined criteria and checklists to assist the process (Oxman, 1994). After the first reading of the complete text, each study underwent repeated readings and was evaluated during these readings to confirm that it met the inclusion criteria, and the findings were summarized in customized form. In most cases, dual inference processes were followed, in which two independent evaluators analyze and compare the publication and, if necessary, reconcile their findings (Tranfield et al., 2003). In this study, the data were analyzed separately by a measurement and evaluation specialist, and a consensus was reached. The findings were then examined by a field expert working on robotic coding. Thus, the credibility of the research was increased by diversifying researchers. We can say that the 15 articles selected at the end of this process exhibit a certain level of academic quality. The systematic review takes time and requires attention to detail. However, it is the most efficient and high-quality method to comprehensively identify and evaluate the literature (Mulrow, 1994).

Integration of Analysis Results

Data extraction forms are used in systematic reviews to reduce human error and bias. They usually include general information (title, author, publication details), study characteristics and specific information (details and methods), and notes on emerging themes with synthesis details (Tranfield et al., 2003).

The researcher first analyzed each selected article separately. Then, an 18-page Word document containing information about each study (author, title, keywords, year of publication, purpose of the study type, sample groups, data collection tools, data analysis techniques, results, and recommendations) was generated for effective data extraction. The researcher focused primarily on the findings/results and discussion/conclusion sections. After extracting the data, the Word documents were analyzed for similarities and differences in the results of each research report/study. Based on the similarities, three main topics were created to present the data in a way that would fit the study's purpose.

A rigorous systematic review process is used in a systematic review to collect the articles, and then a qualitative approach is adopted to evaluate them (Snyder, 2019). In this study, codes, categories, and significant themes were created by content analysis. Next, the themes obtained from the studies were synthesized, and inductive inferences were made. Then, the data analysis process and the findings were explained. A measurement-assessment expert also analyzed the codes suggested by the researcher. The analysis results were then examined by an expert working in the field of robotic coding.

Results and Discussion

The results obtained from the studies on robotic coding in science education were examined and shown in Table 1.

Table 1. Results from studies on robotic coding in science education

Theme	Category	Code	Studies
Results	Cognitive skills	21st-century skills	S4, S7, S9, S12
		Computational thinking skills	S8, S12, S13, S15
	Applications in robotic coding teaching	Integration into disciplines	S2, S4, S5, S6, S12
		Tools/hardware used in the application	S4, S5, S6
	Affective Variables	Interest	S10, S11, S14
		Motivation	S11
		Opinion	S1

Regarding robotic coding studies in science education covered in this study, they mainly focus on cognitive skills; these skills include 21st-century skills (communication, problem-solving, scientific creativity, cognitive process skills) and computational thinking skills (computational thinking, algorithmic thinking, mathematical understanding). Application studies follow them. These applications are mainly in science and engineering, and Arduino and tablet applications are used. Finally, the studies on affective variables focused on interest, motivation, and opinion. The suggestions of the studies on robotic coding in science education were examined and shown in Table 2.

Table 2. Suggestions of the studies on robotic coding in science education

Theme	Category	Code	Studies
Suggestions	Application	Integration of robotic coding (field, subject, educational environment-in-service training)	S2, S9, S11, S12
		Using robotic coding at different learning levels	S5, S7, S12
		Carrying out studies on teaching robotic coding	S4
		Carrying out studies on the use of different robotic coding programs	S15
	Future Research	Large scale studies	S1, S3, S8
		Using different data collection tools	S8, S14
		Further and in-depth research	S10
		Studies addressing gender variable	S13

The suggestions for robotic coding studies in science education are mostly related to applications and future research. The integration of robotic coding is the most mentioned suggestion for the application. These integrations cover STEM fields, different subjects, educational environments, and teacher training. This suggestion is followed by using robotic coding at different learning levels, carrying out studies on teaching robotic coding, and using different robotic coding programs.The most mentioned suggestion for future research is conducting large-scale studies, followed by using different data collection tools, carrying out further and in-depth research, and addressing the gender variable.

Conclusion

This study is considered important for revealing the trend in studies carried out in coding and robotics between 2015-2022. In addition, it is thought that it will guide future researchers who will make robotic coding in science education. Thus, the results obtained from the publications on robotic coding education in science education are discussed in this study.

Regarding the results of robotic coding studies in science education, they mainly focus on cognitive skills related to 21st-century skills (communication, problem-solving, scientific creativity, cognitive process skills) and computational thinking skills (computational thinking, algorithmic thinking, mathematical understanding). In addition, robotics technology supports the development of scientific concepts and scientific inquiry skills (Williams et al., 2007). Therefore, coding education is essential to the education of people who are equipped with 21st-century abilities, such as effective use of technology, problem-solving, and product development. Theodoropoulus et al. (2017) reported that students participating in an educational robotics competition better understood STEM concepts (Negrini & Giang, 2019). Coding contributes to individuals' acquisition of 21st-century skills. The problem-solving (Lee et al., 2011; Selby & Woollard, 2013), computational thinking, algorithmic thinking, spatial and analytical thinking skills of the students who learned to program were improved (del Castillo et al., 2019; Demirer & Sak, 2016; Monroy-Hernández & Resnick, 2008; Shin et al., 2013; Tsukamoto et al., 2017; Wing, 2006).

Then comes studies on applications in robotic coding teaching. These applications mainly involve science and engineering, and Arduino and tablet applications are used in them. According to Catlin and Robertson (2012), teaching algorithms and programming tools to students will improve their digital literacy, increase their interest and attention to school and lessons, develop problem-solving and metacognitive skills, and increase their habits of learning by doing and learning by teaching. In the last few years, many countries, seeing the value of programming, computer science, and computational thinking, have tried to change the curriculum and integrate coding into courses, which provides the required skill for computer programming (Duncan et al., 2014; Guven et al., 2022). As a result, students can integrate courses through robotics and coding education, supporting their cognitive thinking skills and learning. Jung and Won (2018) argue that studies should target how to adopt robotics in school contexts and how to adapt robotics to the current curriculum of the courses. This situation brings to mind the question of "how competent the teachers, who play an essential role in practice, are in robotic knowledge and skills." A study conducted by Wong et al. (2015) to determine the difficulties of integrating coding education into school programs revealed that teachers need training and have shortcomings regarding the curriculum. In many countries, various educational activities are organized for teachers to disseminate educational robotic activities in educational institutions (Kim et al., 2015).

The studies on affective characteristics focused on interest, motivation, and opinion. Robotics activities increase interest (Curzon, 2014; Liang et al., 2013) and motivation (Álvarez & Larrañaga, 2015; Bazylev et al., 2014;

Daher, 2022; Demirer & Sak, 2016) as they allow students to create their own products and support their learning (Lin et al., 2012; Liu et al., 2013). The results of this study support the results in the literature. However, some studies found no significant difference in students' interest, confidence, satisfaction, and motivation levels according to the use of robots in education (McGill, 2012).

Recommendations

This study aims to examine different aspects of coding and robotics education studies and share their results and suggestions with researchers. The following recommendations can be made as a result of this study. The results of robotic coding studies in science education show that they mainly focus on cognitive skills. Although these skills include some 21st-century skills, some other 21st-century skills were not addressed. Therefore, further studies addressing today's popular skills, such as innovation, critical thinking, problem-solving, cooperation, adaptation, initiative, leadership, responsibility, knowledge, media, and technology, are needed. In addition, alongside 21st-century skills, these studies included computational skills, which are related to the mathematics discipline. Therefore, there is a need for studies that include skills related to other areas of coding education as a subject under STEM education (science [scientific research, scientific reasoning], technology [scientific application and technical knowledge, effective use of resources, creativity, updated products, and systems], and engineering [thinking about design, optimizing iteration, and optimizing]). In mathematics, studies on robotic coding can address the subjects such as models and relationships, data literacy, and mathematical language. On the other hand, studies on cognitive skills mainly involved the integration of coding into science and engineering. Therefore, in science education, it is recommended to plan studies integrating robotic coding into other fields (technology, engineering, mathematics). In addition, there is a need for studies that use other tools used in coding education (Microsoft Small Basic, Alice, MIT App Inventor, and Scratch) in addition to Arduino and Tablet applications. Furthermore, studies on different affective characteristics (attitude, self-efficacy perceptions, self-efficacy beliefs, self-regulation, etc.) will be beneficial in terms of comprehensive coverage of the subject. In addition, studies can be carried out to raise code literacy awareness among students.

Regarding the results of the robotic coding studies in science education, no studies were related to the psychomotor domain. For this reason, it is recommended to include psychomotor characteristics in future studies. The suggestions for robotic coding studies in science education were mostly related to applications and future research. The integration of robotic coding was mentioned more in application suggestions. However, there are no suggestions for curriculum development. Future studies should also address curriculum development related to robotic coding.

The review of the studies in terms of their results revealed that they are mostly skill-oriented, whereas their review in terms of suggestions revealed that they mainly included applications. Teachers play a significant role in the implementation. From this point of view, in-service training on robotic coding applications should be organized for teachers.

This study is limited to 15 articles from WOS and Scopus databases, published between 2015-2022 as full-text. The current study systematically reviewed robotic coding studies in science education. In future studies, researchers should analyze robotic coding studies in different fields and periods using other types of systematic reviews like meta-synthesis or meta-analysis.

Scientific Ethics Declaration

The author declares that the scientific, ethical, and legal responsibility of this article published in the JESEH journal belongs to the author.

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