

## Integrating GIS into Science Classes to Handle STEM Education

Serhat ERCAN<sup>1</sup> , Esra BOZKURT ALTAN<sup>1</sup>, Bekir TAŞTAN<sup>2</sup>, İbrahim DAĞ<sup>3</sup>

<sup>1</sup> Assistant Prof. Dr., Sinop University, Faculty of Education, Sinop-TURKEY

<sup>2</sup> Lecturer, Sinop University, Faculty of Education, Sinop-TURKEY

<sup>3</sup> Science Teacher, Ministry of National Education, Sinop-TURKEY

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### ABSTRACT

STEM stands for science, technology, engineering and mathematics and is an approach to education that aims to integrate these four separate disciplines. In theory, the idea of integration is clear, but in practice in a school setting it proves to be problematic due to the current structure of the educational curricula. In the current structure of educational curricula, usually only mathematics and science courses from STEM disciplines are included in school programmes and these courses are conducted in an isolated manner separate from other disciplines. This problem may be overcome by using interrelated applications such as the Geographic Information Systems (GIS) to integrate mathematics and science courses within STEM disciplines. As an interdisciplinary technology, GIS serves as a pedagogical tool for use in STEM education. Using a qualitative research paradigm, the current study evaluated a sample of junior (third-year) science teacher candidates (N=34) in a STEM educational setting using GIS. The data was collected from the written science texts of teacher candidates (e.g. the role of GIS in STEM teaching and science teaching; the implementation of STEM education in science classes) before and after the teaching intervention. At the end of the study, it was discovered that a four-week long teaching intervention had a positive effect on the science teacher candidates' views of implementing STEM as well as improving their views on and awareness of GIS.

**Keywords:** Geographic Information Systems (GIS); Integrated Education; Science Teacher Candidates; STEM Education.

### INTRODUCTION

In conjunction with the concepts of technological innovation (Çorlu, Capraro & Capraro, 2014; Porter, Roessner, Oliver & Johnson, 2006), economic development (Archer, DeWitt & Dillon, 2014; Nugent et al., 2015; Williams, 2011) and a qualified work-force (Christensen, Knezek & Tyler-Wood, 2015; Meng, Idris & Eu, 2014), the STEM approach to education has been the focus of international organisations, governments, politicians, industrial enterprises and civil society organisations as well as educators because of what it promises to deliver (Adamuti-Trache & Sweet, 2014; English, 2015). From such a varied group of stakeholders, the question "What is STEM education?" can elicit multiple perspectives (Breiner, Harkness, Johnson & Koehler, 2012). This question can only be answered by an approach that targets the integration of science, technology, engineering and mathematics disciplines and considers it from an educational perspective (Chiu, Price & Ovrhim, 2015; Dugger, 2010; Meng et al., 2014). The work of STEM professionals is



Corresponding author e-mail: [ercanserhat4@gmail.com](mailto:ercanserhat4@gmail.com)

consistent regarding their understanding of education in this context (NAE & NRC, 2009; Wang, 2012) and they see it as better serving learners by connecting them with matters of everyday life (Breiner et al., 2012; Chiu et al., 2015; Harrel, 2010). This is because the problems encountered in real life cannot be restricted to one specific discipline (Beane, 1991), and necessitates information and skills belonging to different disciplines being used together (Wang, 2012). STEM education requires an integrated education designed in such a way as to enhance students' comprehension of professional STEM activities in real life and to eliminate the boundaries between disciplines (Asghar, Ellington, Rice, Johnson and Prime, 2012; Roberts, 2012).

This integration seems to be clear in theory, but its practical use in the school setting proves to be problematic (Pitt, 2009). Even though there may be many reasons for this implementation-oriented problem (Lederman & Lederman, 2013), the current structure of educational curricula can be said to be one of the main reasons (Bybee, 2010; NAE & NRC, 2009; NRC, 2012; Williams, 2011), because in the current structure of educational curricula, usually only mathematics and science courses from STEM disciplines are included in school programmes (Dugger, 2010; NAE, 2010) and these courses are conducted in an isolated manner separate from other disciplines (Roberts & Cantu, 2012). Under the current structure of educational curricula, integrating the other STEM disciplines into science and mathematics courses is seen to be a comprehensive way to implement STEM education (Dugger, 2010; Roberts, 2012; Sampurno, Sari & Wijaya, 2015). However, the teachers of either science or mathematics who are expected to restructure their classes to implement STEM, will probably only be specialists in their own field (Lederman & Lederman, 2013), and will likely focus on learning objectives specific to their own subject areas (English, 2015; Williams, 2011). Therefore, the realised STEM education will be quite different from the desired STEM education (Breiner et al., 2012).

The teacher is one of the most vital elements in STEM education as in any education reform movement (Han, Yalvac, Capraro, & Capraro, 2015). Teachers' competency related to the STEM approach needs to be developed for its successful implementation (Williams, 2011). Teachers are educated to teach a subject, such as science or mathematics in an isolated manner (Lederman & Lederman, 2013), so require a change in pedagogical orientation for the integrated STEM approach to education to be successful (Han et al., 2015). It is important for teachers to be exposed to STEM experiences through either in-service or pre-service training that allows them to discover contexts necessary for the integration of subjects (English, 2015; Han et al., 2015; Williams, 2011).

One of the applications that teachers should be introduced to is the Geographic Information System (GIS) (Duran, Höft, Lawson, Medjahed & Orady, 2014), which is defined as an interdisciplinary technology (Henry & Semple, 2012), that serves as a pedagogical tool for STEM education (Srisawasdi, 2012), because it renders applications that students use to collect real data, analyses the data and helps students to develop technology-assisted solutions for real-life problems related to the STEM disciplines (Baker & White, 2003; Meyer, Butterick, Olkin & Zack, 1999; Nugent, Barker, Grandgenett & Adamchuk, 2009). The models created by STEM professionals can be built using GIS (Audet & Abegg, 1996; Kerski, 2008), and in addition, issues such as climate change, energy efficiency and the establishment of safe eco-systems where GIS is frequently used (Kerski, 2011), accurately reflect the context required for activities related to STEM education (Bybee, 2010). In short, GIS renders all applications carried out by STEM professionals accessible and applicable for students (Baker, 2012). Such a teaching process enables students to gain a deeper understanding of STEM disciplines (Baker & White, 2003; Kerski, 2008), and positively affects their attitudes towards these disciplines (Aladag, 2014; Whitaker, 2011). When considered from all these perspectives, GIS seems to have the potential to pave the way for

science classes where science and STEM disciplines are carried out at the same time (Patterson, Reeve & Page, 2003).

This study, conducted in the light of these theoretical explanations, focused on how the implementation of a sample STEM education using GIS was assessed by the participating science teacher candidates, and sought answers to the following specific sub-problems:

1. What are the science teacher candidates' opinions on the use of GIS in science education before and after the instruction?
2. What are the science teacher candidates' opinions on the use of GIS in STEM education before and after the instruction?
3. What are the science teacher candidates' opinions on the implementation of the STEM education approach in science classes before and after the instruction?

## **METHODOLOGY**

This study was conducted in accordance with qualitative research methods in a manner appropriate to the nature of research problems and focused on how the implementation of a sample STEM education using GIS was assessed by science teacher candidates.

### **a) Study Group**

A total of 34 science teacher candidates enrolled on the "Laboratory Application in Science Education II" course, and constituted the study group. Included among the outcomes of this course were "the use of technology in laboratory works for science education" and the "design and implementation of scientific research processes related to topics in the primary school science curriculum", which along with the planned teaching process, were effective in the realisation of this course. A purposeful sampling strategy was used on the study group as is usual in qualitative research (Punch, 2005) and the selection criteria for identifying the participants should primarily be determined by this strategy (Merriam, 2013). Two criteria - "participating in all activities during instruction" and "ensuring a flow of rich information in written texts" - were determined within the context of the study.

Of 83 enrolled teacher candidates, a total of 45 were absent from the four-week long in-school practices for at least a week or failed to participate in field work, so were not included in the study group, and a large number of teacher candidates were absent from the field work. Four teacher candidates were excluded from the study group on the grounds that they did not respond to the open-ended questions directed at them. Therefore, out of the 83 enrolled teacher candidates, a sample of 34 (22 females and 12 males), who met the identified criteria, formed the study group.

Teacher candidates in the study group took the opportunity to learn the theoretical explanations for STEM education within the context of the "Laboratory Applications in Science Education I" course they had previously received. They took part in the practices of the teaching model (Design-Based Learning) for the integration of other STEM disciplines into science classes, within the context of this course. Therefore, the teacher candidates included in the study group can be said to have had a general understanding of STEM education prior to instruction.

### **b) Procedures**

As part of the implementation process of the study that lasted for four weeks (16 class hours), candidates were requested to develop an analysis model in the GIS environment for the properties of freshwater resources located in different residential areas. During the first week of the instructional process (four class hours), they were given instruction in how to use GIS (data collection, database creation, spatial analysis, data visualisation, creation of output

and various software used in the realisation of these processes). Then, working in groups of three to four people, they determined the mathematical location of the freshwater source located in the residential area they were responsible for (with the help of GPS) and collected water samples. Following this field-work, each group analysed their water samples in accordance with the pre-determined parameters (water hardness and pH) and shared the results with other groups on the “laboratory works” course. The process of developing models in the GIS environment was initiated by the candidates after obtaining the data. The candidates created their respective spatial databases, performed data entry, analysis processes and created visual models (density maps) in relation to the results using ArcGIS 10.0 software (under the guidance of an expert). The process concluded with class presentations of reports, prepared by candidates regarding the processes they performed. The instructional process is summarised in Table 1.

**Table 1. Instructional Process.**

Phases of Instructional Process	Performed Activity	Related Content and Practices
1 <sup>st</sup> week	Basic Education for GIS	- Recognition and use of GIS technologies in general
Field work	Collection of water samples	- Recognition and use of GPS technologies - Determination of mathematical location using GPS
2 <sup>nd</sup> week	Laboratory work - Water hardness analysis - pH analysis	- Water hardness and pH concepts - Recognition of technologies used to determine water hardness and pH from the past to the present - Mathematical thinking - Unit conversion among different hardness units
3 <sup>rd</sup> week	Creation of models on GIS	- Selection and use of GIS technologies - Mathematical modelling
4 <sup>th</sup> week	Presentation of study reports and class discussion	- Communication and evaluation

Bybee (2010) notes there can be no single accepted model of STEM education, and Williams (2011) says there are several application models dealing with the approach from different perspectives in the related literature. Despite these views, there are some general criteria that implementations of integrated STEM education should possess (Glancy & Moore, 2013), including enabling teachers to establish connections between STEM disciplines (Bowers, 2015). Teaching content and some practices, such as water hardness, pH concept, GIS technologies, unit conversion and mathematical modelling included in the teaching activity performed, displayed a structure consistent with this criterion by allowing connections to be established between STEM disciplines.

Another criterion is the capacity of teaching activity to provide the participants with the opportunity to experience the process of scientific research using real-life activities (Bowers, 2015; Stohlmann, Moore & Roehrig, 2012). Teacher candidates, working within the framework of a problem consistent with real-life, collected water samples from sources whose mathematical locations they determined with the help of GPS. They analysed the data in “laboratory works” and made sense of the results by analysis using GIS software within the context of the teaching activity performed. The process, carried out by students, was said to allow the realisation of various scientific and engineering practices (NRC, 2012) against another criterion expressed by Bowers (2015). Teacher candidates carried out activities using ArcGIS software such as developing and using models, using mathematics and computational thinking in mathematical models, developing processes, planning and carrying out investigations, analysing and interpreting data and obtaining, evaluating, and communicating

information activities in the scientific research process carried out during the instructional process.

Another suggestion for STEM education was the provision of opportunities for students to choose and use appropriate technological tools in the process of finding solutions and forming answers to problems in a real-life context (Bowers, 2015; Stohlmann et al., 2012). A variety of GIS technologies related to data collection and the creation of mathematical models, and various technological tools for use in the analysis of water hardness and pH (from simple test measurement kits to digital measurement tools) were offered to teacher candidates to use when planning and delivering their teaching within the scope of the study.

The instruction, performed in accordance with all these explanations, can be said to constitute a suitable model for integrated education aimed at different STEM disciplines.

### **c) Data Collection and Analysis**

The study data was collected using written texts in which teacher candidates expressed their opinions regarding the use of GIS in the context of science and STEM education and the implementation of the STEM education approach in science classes. The candidates were asked to express their opinions in written format on designated topics before and after the application.

During data analysis, the written texts of teacher candidates were read line by line in order to determine any significant dimensions of the raw data (Glesne 2013). Using an inductive approach, code lists of data were generated for analysis (Yıldırım & Şimşek, 2008). The codes obtained were revised to reveal connections between them and so they could be categorised and classified. The codes and categories generated by each of the researchers were presented for evaluation by other researchers after the process was carried out separately by two researchers. The codes were finalised and consensus reached after discussion and after the attributed meanings were compared to the categories and codes. Finally, the findings of the study were revealed by organising the data collected within this system. Sample responses included in the presentation of study findings were coded with the letter M for male teacher candidates and the letter F for female teacher candidates. According to this display, the abbreviation in the form of “F<sub>5</sub>”, seen in the presentation, referred to the female teacher candidate with number 5.

## **FINDINGS**

### **a) Findings related to the opinions of teacher candidates on the use of GIS in science education**

The findings obtained from the analysis of the texts written by teacher candidates prior to the instruction were presented in Table 2. Frequency values, expressed in the table, showed the number of evaluations conducted by teacher candidates. Teacher candidates' inclusion of multiple ideas to be assessed in different codes or categories in written texts led to the total number of frequencies indicated in the table to be different from the number of teacher candidates.

As can be seen in Table 2, the opinions of teacher candidates on the use of GIS in science education were evaluated under three categories prior to the application. Candidates were seen to assess the GIS use as a factor contributing to science education in many aspects (motivation, attracting attention, context ...) when examining sample texts presented for the category called “Supports learning”. The 2<sup>nd</sup> category, determined as “Not used”, included the opinions declaring that GIS cannot be used within the context of science education. All of the candidates expressing opinions in this direction stated that there was no relationship between science education and GIS. Candidates' opinions on the use of GIS in science education

which would support various scientific skills found their place in the 3<sup>rd</sup> category determined as “the development of scientific process skills”. When examining the sample texts for this category, it was seen that while F<sub>6</sub> established a direct relationship between the use of GIS in science education and scientific process skills, M<sub>1</sub> pointed out the data collection process. In this regard, the relevant responses of the candidates were assessed under the category called “the development of scientific process skills”.

**Table 2.** *Opinions of teacher candidates on the use of GIS in science education prior to the instruction*

Codes	Categories	f(N)	Sample response
Restricted use for the content			<i>M<sub>3</sub>: There are some topics related to the environment in science curriculum. They can be learnt easily if GIS is used while teaching them.</i>
Draws attention	Supports learning	11	<i>M<sub>5</sub>: ...the use of such computer programs in the class will draw students' attention to that particular course.</i>
Increase motivation			<i>M<sub>11</sub>: Even the use of simplest technologies in class increases student motivation. GIS technologies also facilitate the class by increasing student motivation.</i>
Not related	Not used	7	<i>F<sub>1</sub>: I cannot establish any connection between GIS and science education. In fact, science education is related to many things but I do not know GIS very well.</i>
			<i>M<sub>9</sub>: ...I do not know how this technology can be used in science classes. I think there is not much connection between them.</i>
Data collection	Development of scientific process skills	4	<i>F<sub>6</sub>: ...the development of different skills is also targeted in science education. It can be used to teach skills of scientific process such as collecting, interpreting and modeling the data.</i>
Modeling			<i>M<sub>1</sub>: ...GIS can be used while teaching the locations of different plants.</i>

The findings reflecting the opinions of teacher candidates on the same topic after the instruction were given in Table 3.

It was seen when examining Table 3 that the opinions of teacher candidates on the use of GIS in science education after the instruction were evaluated under 4 categories. The first of them was the category of “Supports learning” which was also called in the same way prior to the instruction. But, at this stage, the candidates were seen to associate GIS with the items highlighted in modern learning-teaching theories such as student-centered teaching and real-life connection in their evaluations. The relationship teacher candidates established between higher-order thinking skills included among the final objectives of science education and the use of GIS was given a place in the context of the 2<sup>nd</sup> category entitled as “higher-order skills development”. F<sub>19</sub> was seen to make an emphasis on the development of problem solving skills when examining the sample response for the category. For this reason, the evaluation made by F<sub>19</sub> was included in this category. Another category, included both before and after the application, was seen to be “the development of scientific process skills”. While the

number of evaluations in this category was four prior to the instruction, this number was seen to increase to eight after the instruction. The opinions on the use of GIS in science education, which can be evaluated in the axis of technology literacy such as positive attitude towards technology and skills development, were included in the last category entitled as “contribution to technological literacy”.

**Table 3.** Opinions of teacher candidates on the use of GIS in science education after the instruction

Codes	Categories	f(N)	Sample response
Real-life context			
Student-centered			<i>F<sub>20</sub>: ...in other words, GIS-assisted science education enables students to establish a relationship with real-life.</i>
Increases motivation	Supports learning	16	<i>F<sub>22</sub>: ...it makes the class more meaningful for students and this may lead to meaningful learning.</i>
Suitability for the content			<i>M<sub>6</sub>: Units in science are related to life, GIS is something used in real life and therefore GIS can be used to teach most of science subjects.</i>
Meaningful learning			
Problem solving	Higher-order skills development	3	<i>F<sub>19</sub>: We carried out real practices related to science in the application we performed. We solved a real problem. Performing these kinds of practices will definitely develop students' problem solving skills.</i>
Creativity			
Data collection			
Data analysis	Development of scientific process skills	8	<i>F<sub>6</sub>: ...it can be used in teaching scientific process skills such as data collection and analysis.</i>
Modeling			
Attitude towards technology	Contribution to technological literacy	6	<i>F<sub>4</sub>: ...students already use the technology well; it will become more meaningful when they see that the technology serves their purpose in this way. Their attitudes towards technology will become positive.</i>
Technological skills development			<i>F<sub>15</sub>: ...using these programs will increase their skills, the more technology is used in classes, the more developed the students will become.</i>

It was observed when evaluating all these findings obtained before and after the instruction together that teacher candidates discovered deep connections between GIS and science education depending on the instruction performed and considered GIS applications as a necessity for the final objectives of science education (problem solving, creativity, etc.) as different from before the instruction.

### b) Findings related to the opinions of teacher candidates on the use of GIS in STEM education

The majority of candidates (n=21) provided no response when they were asked to state their opinions on the use of GIS in STEM education prior to the instruction. It was stated in all of the few responses given in this regard that GIS would only reflect the technological dimension of STEM education. Samples on the responses given were as follows:

*M<sub>3</sub>: All disciplines should be included in STEM education. GIS technologies constitute its technological dimension.*

*F<sub>1</sub>: The technology that should be included in applications for STEM education is supplied in this way.*

The findings reflecting the opinions of teacher candidates on the same topic after the instruction were shown in Table 4.

**Table 4.** Opinions of teacher candidates on the use of GIS in STEM education after the instruction

Codes	Categories	f(N)	Sample response
Inserting Technology	Inserting Technology	9	<i>M<sub>10</sub>: ...all the fields should be included for STEM implementations in classrooms. Science is already simple because subjects are chosen from there. The field of technology will also be included in implementations by using GIS.</i>
Real-life context	Pedagogical tool	16	<i>F<sub>3</sub>: ...science, technology, engineering and mathematics were all included in the implementation we conducted. GIS brings all disciplines together for STEM education.</i>
Integration of all the disciplines			<i>M<sub>1</sub>: We always talked about the necessity of real-life context for STEM education in laboratory classes. We thought that it would only be possible with engineering designs there. But, we can exactly tell that this is the real-life context after seeing GIS application.</i>
Interest in technology	Interest in STEM disciplines	14	<i>M<sub>4</sub>: ...these applications will increase students' interests in STEM fields such as technology and science.</i>
Interest in science			<i>M<sub>8</sub>: ...we worked like a computer engineer while creating database in the program. Doing such a work with computer will attract the attention of students and increase their interest in engineering and technology.</i>
Interest in engineering			

As can be seen in Table 4, the opinions of teacher candidates on the use of GIS in STEM education after the instruction were evaluated under 3 categories. The first of these categories included the opinions of candidates that GIS would reflect the “T” (technology) dimension in STEM education as stated by candidates prior to the instruction. For this reason, the response given by M<sub>10</sub> would constitute as a sample for this category entitled as “inserting technology”. It was seen when examining this response that the candidate put emphasis on the inclusion of different STEM disciplines into a class before referring to the connection between these disciplines and considered GIS as a means of inserting technology a bit into science class. The opinions in which candidates considered GIS as an educational tool that meets with the requirements for the implementation of STEM education were included within

context of 2<sup>nd</sup> category entitled as “pedagogical tool”. Two of the responses, evaluated under this category, were given by F<sub>3</sub> and M<sub>1</sub>. It was observed when examining these responses that while F<sub>3</sub> considered GIS as a tool for the integration of STEM disciplines, M<sub>1</sub> regarded it as an application that transports the real-life context required for this integration into classrooms. The opinions of teacher candidates on the use of GIS in STEM education would increase students’ interests in STEM fields were included within the context of the last category entitled as “interest in STEM disciplines”.

It was seen when examining the findings obtained prior to and after the instruction that the candidates, who regarded GIS to be associated only with technology from STEM fields prior to the instruction, considered it as a ground reflecting the real-life context needed for STEM education and a tool providing the integration of STEM disciplines naturally after the instruction. In addition, the candidates stated after the instruction that such a relationship would increase students’ interests in STEM disciplines.

### c) Findings related to the opinions of teacher candidates on the implementation of STEM education approach in science classes

The opinions prior to the instruction were firstly included in this section in which the opinions of teacher candidates on the implementation of STEM education approach in science classes were assessed. Table 5 prepared in this regard was shown below.

**Table 5.** Opinions of teacher candidates on the implementation of STEM education in science classes prior to the instruction

Codes	Categories	f(N)	Sample response
DBL	Applicable	19	<i>F<sub>21</sub>: We saw in our previous laboratory classes that design tasks enabled STEM education. In other words, science classes, conducted by means of engineering designs, provided STEM education.</i>
			<i>M<sub>8</sub>: Design-based science education can be performed in order to conduct STEM education.</i>
Inapplicable	Inapplicable	12	<i>M<sub>1</sub>: I think that the programs need to be changed for STEM education. We are required to learn science in science class through this program, but other fields should also be taught in STEM education.</i>

As can be seen in Table 5, the evaluations of candidates on the implementation of STEM education approach in science classes concentrated on two categories as being “applicable” and “inapplicable” prior to the instruction. All the candidates, who expressed opinions as “applicable”, were found to put the emphasis on Design-Based Learning (DBL) which they were familiar with within the context of classes they received prior to teaching activities. Opinions related to the non-realization of STEM education in science classes were included within the context of another category entitled “inapplicable”. In his response which could constitute as an example in this category, M<sub>1</sub> stated that the current science curriculum should be implemented in science classes and this program was not designed within the context of STEM education and therefore, STEM education could not be implemented in science classes under current conditions.

The evaluations of teacher candidates on the implementation of STEM education approach in science classes after the instruction were presented in Table 6.

**Table 6.** *Opinions of teacher candidates on the implementation of STEM education in science classes after the instruction*

Codes	Categories	f(N)	Sample response
DBL GIS			<i>F<sub>5</sub>: We were only aware of DBL for transforming science classes into STEM classes. We discovered in this application that GIS was also beneficial for this purpose.</i>
Different applications	Applicable	41	<i>M<sub>7</sub>: We did not know that such a lesson could be conducted by GIS prior to this application. In my opinion, there are certainly other applications allowing the implementation of STEM in science classes.</i>

As can be seen in Table 6, all of the assessments, made by the candidates after the instruction, were in the direction of the applicability of STEM education in science classes. It was seen when evaluating these findings together with the findings prior to the instruction that the opinions which some candidates possessed on inapplicability of STEM education in science classes showed changes after the instruction and the candidates held some beliefs that an education in this direction could also be structured in different forms.

## CONCLUSION and DISCUSSION

The results of this study on how the implementation of STEM education structured using GIS changed the opinions of teacher candidates, were discussed within the framework of sub-problems. First of all, the opinions of teacher candidates on the use of GIS in science education were scrutinised. It was seen that the candidates perceived GIS as a factor facilitating learning in science education prior to the instruction, and were able to defend their opinions by generating appropriate arguments after the instruction. In addition, the candidates were observed to establish deep connections between science education and GIS and considered GIS applications a necessity for the ultimate objectives of science education (problem solving, creativity, etc.). Technology literacy stood out as an area where there had been a change in the opinions of teacher candidates regarding the use of GIS in science education. Making no evaluation on this aspect before instruction, after instruction the candidates stated that using GIS in science education would contribute to students enhancing their attitudes towards technology and improving technologic skills.

When addressing these assessments from the perspective of science education curricula (MEB, 2013), teacher candidates considered the use of GIS in science education beneficial for student improvement in all areas (knowledge, perception, skills, science-technology-society-environment) of the curricula.

The assessments of teacher candidates on the contribution the use of GIS in science education would make included inferences made on the basis of their teaching experience, which is supported in the relevant literature. For example, in the study carried out using innovative technologies (GPS, GIS, probes, sensors etc.) in authentic research contexts, Ebenezer, Kaya and Ebenezer (2011) noted that students' scientific inquiry abilities and perception contributed to their fluency with innovative technologies. As a consequence, it can be argued that the instructions have contributed to raising awareness of the potential of using GIS in science education in science teacher candidates'.

In line with the findings associated with another sub-problem of the study in the relationship between GIS and STEM education, the candidates' perspectives of initially only considering GIS as a "T" component of STEM substantially changed after the instruction, and they were seen to consider it as a basis for reproducing a real-life context required for STEM education as well as a tool for ensuring the integration of STEM disciplines (Audet & Paris, 1997; Kerski, 2003; Srisawasdi, 2012). They were also found to consider GIS an important factor in increasing interest in STEM disciplines (Nugent, Barker, Grandgenett & Adamchuk, 2010). Furthermore, the candidates' limited perception on the integrated nature of STEM education prior to the instruction was seen to undergo a positive change after instruction. In conclusion, the instruction performed, greatly developed science teacher candidates' understanding of STEM education (Baker, 2012).

Finally, the opinions of candidates with regard to the sub-problem of the implementation of STEM education in science classes, which they indicated was non-realizable or only realizable with DBL prior to the instruction, also underwent a change after the instruction, and all candidates expressed opinions on the practicability and necessity for integrated education in science classes. In addition, the candidates also evaluated the availability of different ways to integrate other than DBL in which they had prior experience and GIS which they used in this instruction. It can be said that the instruction performed increased candidates' beliefs on the practicability of STEM education in science classes. This progression in the beliefs of science teacher candidates on the implementation of STEM education in their respective classes is important for the promotion and dissemination of STEM education in Turkey.

It is obvious that Turkey, which is expected to make a breakthrough in technological innovation for sustainable development, will require a qualified work-force who have received training in STEM fields (TUSIAD, 2014). Addressing integrated teaching related to STEM fields at all levels of the Turkish education system is seen as a necessity in order to achieve this goal (TUBITAK, 2004).

In Turkey, in contrast to technology and engineering, science and mathematics have established learning standards and a long history in the K-12 curriculum. Consequently, the most convenient way to implement STEM education in K-12 schools around the country is to integrate other disciplines into science and mathematics courses. However, science and mathematics teachers in Turkey are only specialised in the teaching of their respective disciplines in teacher training programmes. They cannot find the opportunity to develop their proficiencies in integrated education that requires different pedagogical perspectives, strategies, and tools from the discipline based education they have received. Because teachers are constructing their own knowledge of teaching in instructional settings (Shulman, 1986), science and mathematics teacher candidates should be given the opportunity to take part in STEM education implementation, as in this study, in order to develop their proficiency in integrated STEM education.

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