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STEM Images Revealing STEM Conceptions of Pre-Service Chemistry and Mathematics Teachers

Sevil Akaygun, Fatma Aslan-Tutak

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Abstract

Science, technology, engineering, and mathematics (STEM) education has been an integral part of many countries' educational policies. In last decade, various practices have been implemented to make STEM areas valuable for 21st century generation. These actions require reconsideration of both pre- and in-service teacher education because those who touch students in and out of the class settings are the teachers. In this respect, this phenomenograhic study aimed to investigate how STEM conceptions of pre-service chemistry and mathematic teachers' (N=38) evolve as they work together through a STEM module, Collaboratively Learning to Teach STEM (CLT-STEM), depicted by the posters they prepared in groups before and after the implementation. The posters were analyzed with respect to two aspects; conceptions of STEM as a whole, and conceptions of each STEM area individually. For the conceptions of STEM, the codes emerged from data were used; whereas for the conceptions of each STEM area, definitions of these areas were referred. The results of the analyses revealed that the STEM conceptions of the majority of pre-service chemistry and mathematics teachers improved from a lower to a higher level of conception. In terms of the conception of each STEM areas individually, pre-service teachers refined their conception of each area by representing less detail, rather a more comprehensive and integrated view. Therefore, this study may encourage implementing STEM education in preservice science and mathematics teacher education.

Introduction

As the scientific and technological developments accelerate the world everyday, the need for the skilled work force who will take part in this endeavor increases. The skills that 21st century citizens are required to survive in the modern world include communication, critical thinking, creativity and collaboration (Partnership for 21st Century Learning, 2015). The need for these skills made it imperative for students to experience such learning environments. Teachers are the designers of the learning environment so that they should be able to provide such environment to students. As learning science and mathematics disciplines gain importance in the digital age, 21st century citizens need to have content knowledge of science and mathematics in order to apply them in technology and innovation. When all of these considered, Science, Technology, Engineering, and Mathematics (STEM) education provides practices for 21st century education.

As this special issue calls for attention on STEM education, it is also important to provide opportunities for teachers to learn STEM education. As STEM definition emphasizes interdisciplinary study and collaborative work instead of isolated disciplines, addressing STEM education in high school becomes more important. Due to higher level abstract study of subject matters in high school, disciplines are usually being taught separately. Many high school teachers have limited interaction with teachers from other subject areas (Rockland et al., 2010). However, teachers should experience 21st century skills themselves to be able to provide such learning experiences to students. Even though there have been some initiatives (e.g. curriculum statements) to connect related subject areas during instruction, usually teachers of a specific area use examples from another area to motivate students rather than to teach important ideas.

In many countries, science and mathematics teachers use more real-life applications in their classrooms so students will learn how to use their knowledge in different areas. Also, teachers include new technologies in instruction because their students are natives of digital age. However, all things considered, separate efforts in improving science and mathematics education without appropriate technology integration may lead to isolated packs of knowledge which cannot be used in an interdisciplinary problem solving situation. For example, many times, a science teacher complains about her students' inability to transfer their mathematics knowledge to science subjects. Even though, students may solve mathematics problems in a science context, they may just focus on the mathematical operations and miss out the relationship between science and mathematics.

The STEM education definition that the authors of this article adopted emphasizes using STEM education to teach important ideas in subject areas while providing integration (not just connection) between disciplines (Dugger, 2010). In other words, STEM is more than putting areas together (S+T+E+M) to teach them separately or in relation with each other. As one chemistry and one mathematics educator, we started working together collaboratively and decided on a STEM definition which evolved further as we worked on STEM education project. The STEM education definition that we take as foundation for this project comes from Dugger (2010). Dugger discusses four approaches to STEM education. All four approaches will be discussed in literature review section of this article. Dugger's fourth approach is infusion of all STEM areas. “A more comprehensive way is to infuse all four disciplines into each other and teach them as an integrated subject matter” (p.5). As STEM education researchers, we choose to implement this infusion approach in our research and in STEM education workshops done with pre and in service teachers.

With this infusion definition, we developed a STEM education module, Collaboratively Learning to Teach STEM (CLT-STEM) to be implemented with chemistry and mathematics preservice teachers while they are taking corresponding teaching methods courses. In CLT-STEM Module, the focus was on implementing and developing STEM activities to teach chemistry and mathematics. Preservice teachers experienced various STEM activities and worked in small groups of different subject areas to design/develop STEM activities. When Corlu, Capraro and Capraro's (2014) STEM education definition considered, STEM education implementation in this research project highlights discipline-based approach in which knowledge, skills and beliefs are collaboratively constructed by students and teachers at the intersection of more than one STEM subject area.

STEM Education

As the transition to Information Age (i.e. Digital Age) from Industrial Age, there is need for human force for technology and science related jobs. In this sense, the people of the information age are required to be literate in STEM disciplines, think interdisciplinary and work collaboratively to solve complex real-world problems (e.g. environmental problems) and take action in practical applications. To this end, not only at the secondary but also at post-secondary level, students should be educated to meet these needs to become STEM literate citizens and join the STEM work force (Dugger, 2010).

The emerging need for educating the new generation according to the needs of 21st century made educators bring an integrated approach, *STEM education*, in shape. The pioneer of STEM as term was Ramaley by using the term in 2001 to refer a curriculum which addresses these subject areas (Teaching Institute for Excellence in STEM, 2010). Today, as commonly accepted, STEM education is defined as an interdisciplinary approach to learning where concepts are matched with real-world lessons as students apply science, technology, engineering and mathematics in contexts to make connections between school and the society for the development of STEM literacy (Tsupros, Kohler, & Hallinen, 2009). Similarly, according to Dugger (2010), STEM highlights integration of the mentioned subject areas as a new cross-disciplinary subject in schools. With this respect, Dugger (2010), describes four ways to teach STEM at PK-12 level; as teaching subjects isolated as an independent subject (S-T-E-M), as putting emphasis on one or two subjects (SteM), as integrating one of the STEM disciplines into the other three (E→S-T-M), and finally, infusion of all four disciplines into each other. All in all, “STEM education offers students a chance to make sense of the integrated world we live in rather than learning fragmented bits and pieces of knowledge and practices about it” (p.2). Furthermore, Corlu et al. (2014) discussed innovation and STEM education, and defined STEM education as “the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area” (p.75).

STEM Education Policy and Practices

Despite the increase in the demand for having the workforce of scientists, technologist, and engineers, a decrease in the interest of pursuing STEM careers for many students have been reported all around the world (Osborne, Simon & Collins, 2003; NSB, 2008; Sanders, 2009; Cavas, 2012). To this end, many educational initiatives have taken place to promote STEM education amongst students, teachers and general public. Digital Age requirements became more demanding for developed countries so the first STEM initiatives came from the U.S. and European Union countries to maintain development in Digital Age. In addition to development of STEM interest in these two regions of the world, there has been a growing interest in STEM in Turkey too. As a developing country, Turkey has to provide big leap in STEM areas (STEMTUSIAD, 2015)

Previously, in the U.S., STEM education was supported by a number of projects such as *Technology for All Americans Project (1994-2005)* and *Standards for Technological Literacy: Content for the Study of Technology (2000-2007),* funded by the National Science Foundation (NSF) in the early 2000s (Dugger 2010). In another efforts to support STEM education, in the US, was determined after the report called, "Tapping America's Potential: Education for Innovation" released by a group of leading business and technology associations in 2005 (Tsupros et.al, 2009). In this report, the committee highlighted several actions to be carried out, as building public support, for making improvement in STEM performance a national priority, to motivate students and adults to study and enter STEM careers, and to upgrade K-12 mathematics and science teaching to increase student achievement. These actions aimed to bring STEM education to all the citizens by targeting the current and future students as well as the general public. As a result of this report, in 2007, National Governors Association (NGA) granted to establish STEM centers to target to the development of a statewide and regional STEM networks. A note from the press release given by the NGA:

STEM Centers will help state K-12 education systems ensure all students graduate from high school with essential competencies in science, technology, engineering and math. These competencies are integral to improving overall high school graduation and college readiness rates and supporting a state economy's innovation capacity related to the businesses that operate within their leading economic clusters.

A similar endeavor towards promoting STEM education has been carried out in Europe as well. European Commission (EC) funded a number of projects such as *Promise, Roberta-EU, Update, Profiles, Pathway, Fibonacci, Parsel, S-TEAM* and *Engineer* in the context of Sixth Framework Programme (FP6) between the years of 2002-2006 (EC, 2015a) and Seventh Framework Programme (FP7) between the years of 2007-2013 (EC, 2015b). Most of these projects aimed to promote STEM education and increase attitudes towards STEM. The effort of EC continues in the same respect. Currently, in the new research programme, Horizon 2020 (2014-2020), EC announced a new call in the pillar of Science with and for Society, SEAC.1. *Innovative ways to make science education and scientific careers attractive to young people*, for the years 2014 and 2015 (EC, 2015c). With this effort, STEM education will be carried out all over the Europe with a special emphasis on coordination and dissemination.

As a result of various attempts to promote STEM education, there has been after-school programs, where students actively involved in STEM practices. For example, Sahin, Ayar, and Adiguzel (2014) examined the effectiveness of an after-school STEM program, *MATHCOUNTS,* which focused on open-ended problem solving activities where students, in collaborative learning groups, choose materials and decide on the methods as oppose to what they normally do in the classroom. As a result, the program became very popular for students, which in turn affected students' choice of STEM areas as a career. This result was also parallel with Maltese and Tai (2010) who indicated that students who experienced STEM practices in early ages are more likely inclined to study in the STEM areas.

Likewise in Turkey, STEM education activities has accelerated within the last decade either by the projects funded by EC, or by The Scientific and Technological Research Council of Turkey, or by other collaborations. The latter one includes various models such as initiatives supported by university's own resources such as *H-STEM & Makers Lab* established by Hacettepe University (H-STEM & Makers Lab, 2015), collaboration of two or more universities (Akaygun et.al, 2015; Aydeniz et.al., 2015), and the by the STEM education themed conferences such as the *2nd International Conference on New Trends In Education - "STEM Education: Establishing A Bridge Across Contexts* (BAU, 2015).

These attempts to improve STEM education in Turkey resulted in improvements in various domains. For instance, Yamak, Bulut and Dundar (2014) reported that working with STEM-based activities helped middle school students improve their science process skills and attitudes towards science. In another study, pursued by Ercan (2014), at the end of a 7-week STEM implementation focusing on Force and Motion, 7th grade students improved their knowledge about engineering, academic achievement in Force and Motion, and decision making skills.

Teacher Education for STEM Education

Today, most of the STEM Education initiatives attempt to make STEM fields and careers interesting and attractive for students (National Science Foundation, 2015). However, there is an urgent need for pre- and in-service STEM teachers to be trained in this respect so that they are able to bring STEM in and out of their classes effectively. In order to have a STEM implemented class, teachers need to hold certain skills and knowledge so that they can integrate technology and engineering concepts into their classroom practices (Zarske, Sullivan, Carlson, & Yowell, 2004). However, Rockland et al. (2010) argue that many of the K-12 teachers have not been trained to implement STEM concepts in their classes and curriculum materials. In addition, Stearns et al. (2012) suggested that important aspect of STEM education is the quality of the activities teachers presented in their classes. The authors assert that increasing the number of science and math lessons does not guarantee the STEM education to be actualized. Both in-service and pre-service teachers need to experience quality STEM activities, and support to develop some by themselves.

There are a number of attempts enhancing teachers' STEM knowledge and skills. Pinnell et al. (2013) developed a six-week program to enhance teachers' knowledge about engineering and design. Ten in-service and 5 pre-service teachers attended the program that includes activities and workshops focusing on curriculum development, inquiry-based learning and the STEM education quality framework. The participating teachers worked with an engineering student, engineering faculty and industrial mentor. The results were significant in terms of achieving the program objectives as all the participants continued to develop STEM capabilities in the following year and provided STEM leadership in their schools.

Nadelson et al.(2012) provided a four-day summer institute for 230 grade 4-9 teachers with the aim of increasing the content knowledge, use of inquiry, and efficacy for teaching STEM of the participant teachers. Their results revealed positive relationships between the participants 'perceptions of their STEM teaching efficacy, inquiry implementation, and comfort with teaching STEM. Another example for an after-school program for in-service STEM teachers was organized in a collaborative project conducted by three universities. In this study, high school science and mathematics teachers participated in a two-day STEM workshop on consecutive Saturdays (Akaygun et.al, 2015). On the first Saturday only the teachers worked on STEM activities in their small groups, and on the next Saturday, they participated with a group of 4-5 students and guided them through the STEM activities. At the end of the two-day workshop, teachers evaluated the workshop and reported their experiences showing an increase in their STEM awareness.

In order for STEM education to be more internalized and effectively adopted in class, it might be suggested to include it as an integral part of the teacher education curriculum. Rockland et al. (2010) suggest that bringing engineering into K-12 classrooms will require modifications of teacher education programs for STEM teachers. This modification includes exposing pre-service teachers to training on engineering concepts by modeling them on how to integrate these concepts into the classrooms. While doing this, they compare engineering design process and scientific inquiry process. Mativo and Park (2012) described a course called "Creative Activities for Teachers" on engineering design process for pre-service teachers offered at University of Georgia. Twelve pre-service teachers took the course which included "demonstration and hands-on learning, including problem solving, designing, and construction and testing of prototypes and activities that increase aesthetic, psychomotor, and cognitive development". The findings showed that the twelve participating teachers generally see the engineering design process as creative problem solving. They found the activities creative and stated that they can use and improve those activities in their future classes.

Similar attempts were also seen in Turkey, Yildirim and Altun (2015) indicated that preservice science teachers who had STEM-based laboratory applications showed significantly higher academic achievement than their counterparts who had traditional laboratory applications. In another study, when preservice science teachers were exposed to STEM education in their laboratory applications for teaching science courses, it was observed that they improved their decision making and science process skills (Bozkurt, 2014). In addition, Bozkurt (2014) reported that preservice science teachers were willing to adopt engineering design-based STEM education in regular science classes when they start teaching.

Under the light of previous studies and the definition of STEM education, the purpose of the study discussed in this article was to investigate the effects of attending a 4-week STEM Education, CLT-STEM Module developed by the researchers, on participating preservice chemistry and mathematics teachers' STEM conceptions. Preservice teachers were asked to prepare a poster at the beginning of CLT-STEM Module and after completing the module. The focus of this article is to examine how participating preservice chemistry and mathematics teachers' conception of STEM evolved as their STEM images depicted through their initial and final posters.

Method

Settings

The study was conducted in Secondary School Science and Mathematics Education Department of a mid-size public university, in Istanbul, Turkey. The department is composed of three programs, Teaching Physics, Teaching Chemistry, and Teaching Mathematics. Students of this department take content courses (e.g. chemistry) for the first three years then start studying pedagogy and area specific teaching methods. In this university, while preservice teachers take both content and pedagogy courses together with the students from other programs, they study area specific teaching methods courses with students in the same program. A STEM education module, *Collaboratively Learning to Teach STEM (CLT-STEM)* was developed by the researchers and implemented with the pre-service chemistry and mathematics teachers during their corresponding teaching methods courses in Fall 2014 semester. There were 30 senior mathematics preservice teachers (17 female, 13 male) and 18 senior chemistry preservice teachers (14 female, 4 male) registered to the corresponding courses.

The authors were also the instructors of the corresponding courses. The CLT-STEM Module designed to last four weeks. First, both chemistry and mathematics teaching methods progressed separately for two thirds of the semester. For the last third, chemistry and mathematics preservice teachers formed groups and worked together for two class hour a week. During the implementation of CLT-STEM Module, participants worked in groups of 3 to 4, consisting at least one chemistry and one mathematics preservice teacher to complete the given tasks. There were 16 groups in total. Twelve groups completed both initial and final tasks of preparing STEM posters. So, the posters of these 12 groups were analyzed in terms of STEM images representing their STEM conceptions.

Their experiences included reading on STEM education, class discussions, three STEM activity implementations and one STEM activity project.. To start with, they were required to read the assigned STEM introduction texts written by Dugger (2010) and Laboy-Rush (2011) for the introduction class. During the class, they started working in their groups to discuss and reflect on the readings. Based on their group discussions, they were asked to prepare a poster illustrating their group's understanding of STEM. All necessary materials (pens, pencils, rulers, poster papers etc) were provided. In order for participants to depict the STEM images, there was no limit or specific instruction on how to do posters. After having 3 STEM activities and a group project at which they were asked to develop a STEM activity with their groups, they were asked to create another STEM poster.

Data Analysis

In order to study the effects of CLT-STEM Module, there has been various forms of data collection; survey administration, individual interviews, video recordings of class discussions, artifact collection and posters created by participants. In this article, we will discuss only the analysis of participating teachers' posters as they create them in their groups and findings of change in STEM conceptions represented in initial and final posters. There were some studies in which analysis of participants' drawings revealed findings that cannot be reached through other forms of data collection (Dahlgren & Sumpter, 2010). One of the earlier forms of picture analysis is draw-a-scientist test (Chambers, 1983) which was developed to examine children's conception of science and scientist (Toğrol, 2013).

In this study, phenomenography was adopted because this type of qualitative research specifically focuses on how different people conceptualize a particular phenomenon in different ways (Orgill, 2007). Marton (1994) claims that there are qualitatively different ways of conceptions and these cannot be considered as 'correct' or 'incorrect'. So, the aim of phenomenography is to identify different possible conceptions which can be reported as 'categories of description' of a phenomenon. In fact, "phenomenographic research is more than simply reporting these different conceptions, it also involves looking for the underlying meanings and the relations between them (Entwistle, 1997). Marton (1994) also suggests that these descriptive categories of conceptions not only be related but also 'hierarchically arranged'. To this end, phenomenography was the most appropriate research method for the purpose of this study because it aimed to elucidate STEM conceptions (studies through STEM images) of preservice teachers.

STEM images depicted through STEM posters were analyzed in two parts: (a) *analysis of the STEM images as a whole representing integration of STEM disciplines,* (b) *analysis of the STEM images representing each STEM discipline.*

a. Analysis of STEM Images, as a whole, representing integration of STEM disciplines

The analysis of STEM images were done based on the codes emerged from the data through open coding. All posters were open coded according to how they approach STEM. Those open codes were used to develop four codes in an order to define STEM and interaction between areas of STEM: Disconnected (1), Connected (2), Complimentary (3), and Integrated (4). The codes can be considered as levels of a continuum. As one end of it is recognizing each of STEM areas separately (Level 1, Disconnected), the other end of it is thinking all areas as intertwined in a way that it is impossible to distinguish them from each other (Level 4, Integrated). In this continuum Level 2, Connected, refers to drawing attention to connection between the areas while still considering them separately. Level 3, Complimentary, on the other hand recognizes the mutual relationships between areas which is more than seeing the connections between areas. Figure 1 shows the conceptions of STEM integration codes emerged from data.

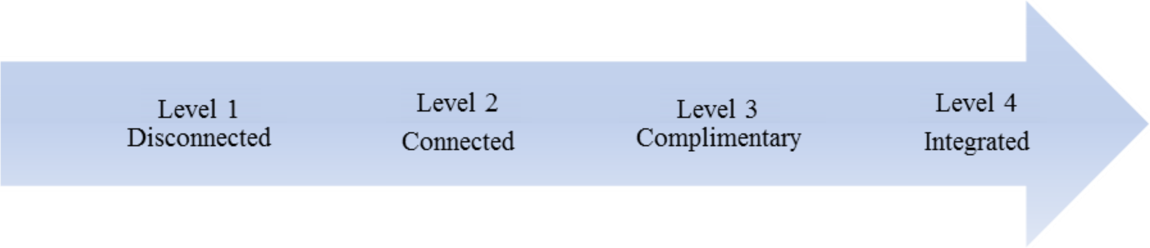


Figure 1. Conceptions of STEM integration codes emerged from data

In addition to conceptions of STEM integration in posters, we also came across with participants' representation of *purpose of STEM education*. All twelve groups for both initial and final posters emphasized a purpose of learning and teaching of STEM education. Similar to STEM conception codes, purpose of STEM education theme derived from the data by firstly open coding and finding emerging codes. Then each poster coded with only one of those codes. There were two main codes for purpose, *definition of STEM* and *goal of STEM education*. Analysis of posters showed that there were two subcodes for each of these purpose of STEM codes. Posters which focused on definition of STEM, either explained STEM or represented the nature of STEM. Posters which emphasized goal of STEM education represented it either as STEM education to change in students' attitudes toward science and mathematics or to improve learning STEM areas. Figure 2 represents the Purpose of STEM Education codes emerged from data.

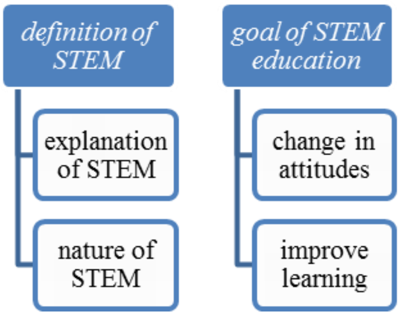


Figure 2. Purpose of STEM Education codes emerged from data

b. Analysis of STEM images representing conceptions of each STEM (Science, Mathematics, Technology, and Engineering) discipline individually

The individual analyses of conceptions of science, mathematics, technology, and engineering were achieved by referring to the definitions of each subject field accepted in the literature. For the definition of *science*, the dimensions identified by American Association for the Advancement of Science (AAAS) (1990) were used. These dimensions include *understanding natural world*, *scientific inquiry*, and *scientific enterprise*. According to the first dimension of this definition, *understanding natural world*, science presumes that universe is a vast system where the basic rules are the same everywhere, and it is understandable by the knowledge gained through seeking the patterns in nature. The second dimension, *scientific inquiry*, implies the role of investigation through qualitative or quantitative methods either by experimentation or collection and analysis of evidence. Finally the third dimension, *scientific enterprise,* emphasizes human endeavor in the scientific activities not only considering individuals performing the act of science but also the role of institutional, social, and ethical aspects. Therefore, the codes used in the analysis of science conceptions were chosen as *understanding natural world, scientific inquiry (tools and processes),* and *scientific enterprise*.

Similarly, the conceptions of *mathematics* were also coded according to the definition of mathematics given by National Research Council (NRC) (1989) “Mathematics reveals hidden patterns that help us understand the world around us. Now much more than arithmetic and geometry, mathematics today is a diverse discipline that deals with data, measurements, and observations from science; with inference, deduction, and proof; and with mathematical models of natural phenomena, of human behavior, and of social systems” (p. 31) including the dimensions of *understanding pattern/chance/algorithm*, *using language or tools, problem solving or modeling*, and *human endeavor*.

The nature of science and mathematics have similarities in terms of their activities because both fields seek to understand natural world and phenomenon around human being with involving knowledge, whereas technology and engineering use the knowledge generated by science and mathematics for practical ends. Specifically, Koehler and Mishra (2008) defined as technology “the tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants” (p.5). In another similar definition given by Arthur (2009), technology is defined a “means to a purpose” or in other words, as a tool that allows individuals to find solutions to problems. As a result, the codes attributed to technology were chosen as *device, process*, and *human benefit*.

Engineering as defined by Accreditation Board for Engineering and Technology (ABET) (1980) is the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes for an intended purpose or function (Encyclopedia Britannica, 2015). Therefore the codes used for the analysis of conception of engineering were *human benefit (purpose), product/structures, process (design and construction)*, and *human endeavor*.

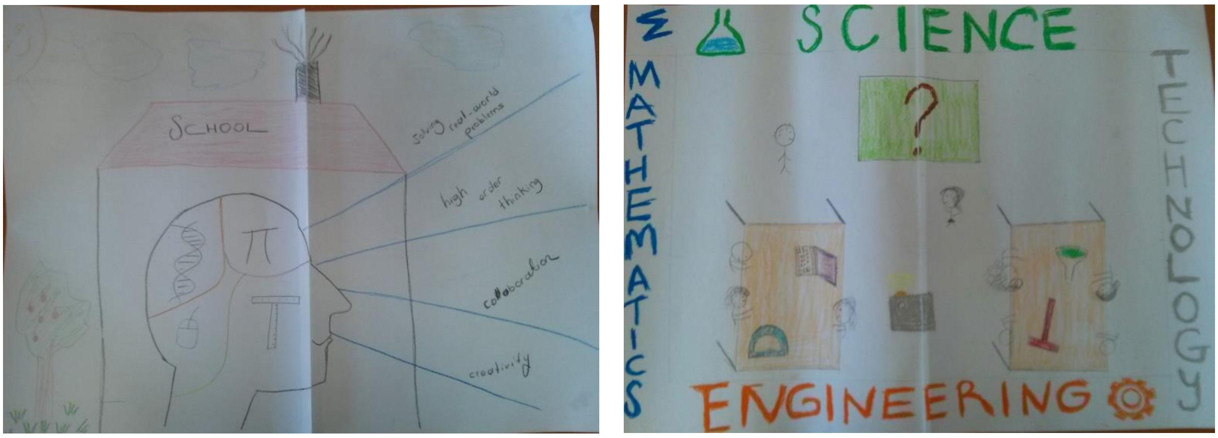
In this research, validity and reliability were taken into consideration from the perspective of qualitative research. In general, validity can be referred as trustworthiness in a qualitative study (Creswell, 2007). Creswell emphasized using credible and dependable analysis procedures to maintain trustworthiness. In this study, in order to establish trustworthiness, for the first part of analysis where the posters were analyzed as a whole to identify representations of integration of STEM disciplines; researchers coded data together, and then asked a a science educator to recode the 25% of the STEM images, interrater consistency was achieved as 100%. In the second part of the analysis, all the codes were generated from the definitions given by the credible, well-known, and world-wide respected authorities such as Mathematical Sciences Education Board.

Furthermore, the data analysis of second part was conducted in three stages; in the first stage, we discussed and developed the coding scheme based on the descriptions given by the credible resources which were discussed above. In the next stage, each researcher coded posters individually according to determined coding scheme. For the final stage, in order to reflect the interdisciplinary nature of STEM, researchers examined each poster together. During this examination, coding scheme was revised and total agreement for each code was established. Then again, the same science educator coded 25% of the posters to determine how each specific discipline of STEM was represented in the STEM images; as a result, an 85% agreement was obtained.

Findings

Conceptions of STEM Integration Represented in the Initial and Final Posters

Amongst 12 groups, for initial posters, there were three posters coded as *disconnected*, five posters coded as *connected*, and four posters coded as *complimentary*. There were no posters coded as the highest level, *integrated*. The analysis of final posters showed that there were two posters coded as *disconnected*, four posters coded as *connected*, four posters coded as *complimentary* and two posters coded as *integrated*. First look at the initial and final poster comparison indicated an increase in the codes of *complimentary* and *integrated*. Furthermore, as initial posters were more clustered around Level 1 and 2, final posters have a distribution of levels with almost half of them coded as Level 3 or 4. In Figure 3, one of the group's, Group X's initial poster and final poster are given. This initial poster was coded as Level 3 *Complimentary* and the final poster was coded as Level 4 *Integrated*.



3(a) 3(b)

Figure 3. (a) Initial poster, (b) final poster of Group X.

Analysis of changes in the conceptions of STEM integration for each of groups' posters showed that seven groups prepared a higher level final poster than their initial poster. Two groups' posters indicated a change from Level 1 to Level 2, three groups from Level 2 to Level 3, one groups from Level 2 to Level 4, and one group from Level 3 to Level 4. While only two group's poster showed a decline from Level 3 to Level 2, three groups' posters remained in same level (one groups for each of Level 1, Level 2 and Level 3). Therefore, most of the groups' posters indicated a positive change in the conceptions of STEM integration. Among three initial posters coded as Level 1, two of them changed into Level 2 in final poster. Also, among five initial posters with Level 2, four of them improved to Level 3 or 4. Table 1 summarizes the changes in the conceptions of STEM integration displayed in the posters.

Table 1. Changes in the conceptions of STEM integration codes

Change	Levels	Number of Groups
Increase	Level 1→Level 2	2
	Level 2→Level 3	3
	Level 2→Level 4	1
	Level 3→Level 4	1
Stable	Level 1→Level 1	1
	Level 2→Level 2	1
	Level 3→Level 3	1
Decrease	Level 2→Level 1	1
	Level 3→Level 2	2

In addition to the conceptions STEM integration represented in posters, participants' perceptions of the purpose of STEM Education were also observed. Each poster was coded with only one purpose code. They either represented STEM to define it or the goal of STEM education. Amongst 12 initial posters, eight of them coded as definition of STEM. In other words, only four groups focused on the goal of STEM education. Whereas, analysis of final posters showed that eight of them emphasized goal of STEM education. In Figure 4, one group's, Group Y's, initial poster and final poster are given. This initial poster was coded as *definition of STEM-nature of STEM* and the final poster was coded as *goal of STEM education-improve learning*.

A detailed analysis of each code also showed the shift in groups' perception of purpose of STEM. Amongst the eight initial posters which were coded as definition of STEM, four of them focused on explaining STEM while four of them stressed the nature of STEM. Two of those groups who focused on explaining STEM in initial posters changed their focus to doing STEM education to improve learning. Other two kept focus on definition of STEM with one for explaining STEM and one for nature of STEM. Similar to groups which were coded with definition of STEM-nature of STEM, two of them changed to doing STEM education to improve learning and two remained same. Furthermore, the three groups who focused on reasons of doing STEM education initial posters also emphasized STEM implementation in final posters. Among those three posters, two of them were coded as improving learning in STEM areas and one group as change in attitudes. All three final posters of those groups coded as improving learning in STEM areas.

4(a) 4(b)

Figure 4. (a) Initial poster, (b) final poster of Group Y.

Conceptions of Science, Mathematics, Technology, and Engineering, Individually Represented in the Initial and Final Posters

Conceptions of 'Science' Represented in the Initial and Final Posters

When the initial and final posters prepared by the groups (n=12) were analyzed with respect to the codes taken from the definition of science, it was found that, initially 8 out of 12 posters included more than one code and 2 groups had only one code. Five posters included two dimensions, and three of them included all three aspects of science. On the other hand, 2 of the posters didn't include any specific codes for science because they had created a more *integrated* poster that didn't show subject fields separately. Interestingly, the majority of the posters, 7 out of 12, included the code of *understanding the natural world* and similarly, again 7 out of 12 posters showed the code of *scientific inquiry*, either by showing a laboratory tool such as erlenmeyer flask or a process occurring such as experimentation. Whenever the code *scientific enterprise* or *human endeavor* was seen, in 6 of the cases, it was not shown by itself, rather it was given in addition to other codes.

When the post posters were analyzed, it was noticed that, again two posters, one of which belonged the same group, didn't show any specific codes of science but displayed a more holistic, *integrated*, model. Five groups had only one code, 4 groups had two kinds of codes and only one group had all three codes. The code of *understanding the natural world* was still shown by the majority of the groups, 7 out of 12; and the code of *scientific inquiry* was given by five of the groups. The code of *scientific enterprise*, which was shown by 3 groups was again given as an additional code to the others as if giving the message of role of human in the other two dimensions. Table 2 shows a summary of findings from the analysis of initial and final posters with respect to their conceptions of science.

Table 2. Number of groups represented various conceptions of 'science' in the initial and final posters

Conceptions of 'science' represented in the posters	Number of groups showed in the initial posters (n)	Number of groups showed in the final posters (n)
Understanding natural world	7	7
Scientific inquiry – tools	3	6
Scientific inquiry – processes	6	3
Scientific enterprise	6	3

The last but not least, it was noticed that from initial to final poster preparation, groups decreased the number of codes, and the details they used in their depictions. In other words, the trends of going *from more to less detail* and *from more individualistic to more holistic* were observed. Figure 5. is an example depicted by Group Z, showing these trends from (a) initial to (b) final posters regarding the conception of science. In the initial poster, in the thoughts of a boy, science was depicted by an apple including an earthworm, pulling down by the gravitational force. The depiction of science in this initial poster was coded as *understanding the natural world*, due to the apple, worm, and the force, *scientific inquiry* due to the observation of nature, and *scientific enterprise* as the human was connected to the process of science. In the final poster, science was depicted by a formula, V=a.t, which was coded as *understanding the natural world.*

Figure 5. (a) Initial poster, (b) final poster of Group Z.

Conceptions of 'Mathematics' Represented in the Initial and Final Posters

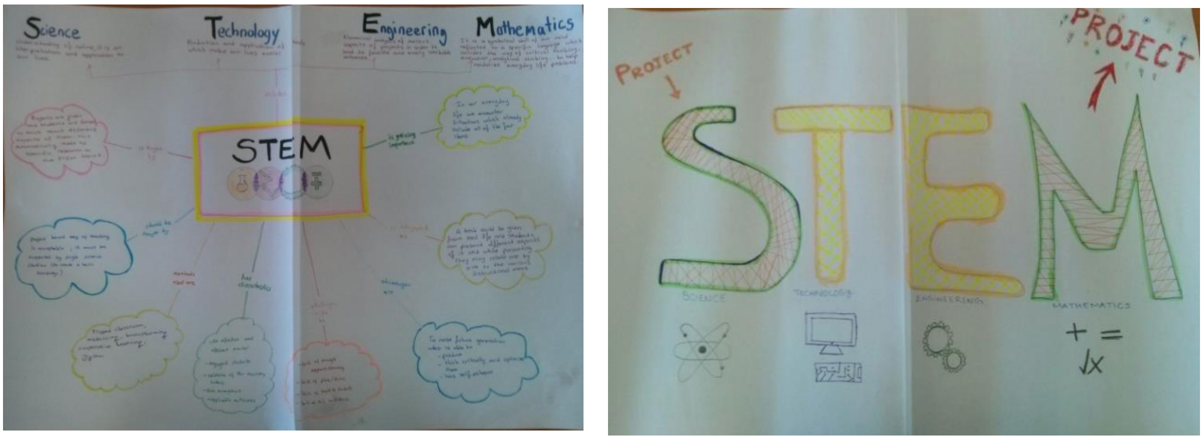
When the initial and final posters were analyzed with respect to the codes based on the definition of mathematics in the literature, as groups *understanding pattern/chance/algorithm*, *language or tools, problem solving or modeling*, and *human endeavor*. In the initial posters, similar to science conceptions, it was found that two group didn't use any codes but represented a more holistic view. Only one group used only one code, 5 groups used two codes, 2 groups used three codes and 1 group used all four codes. When the codes specifically analyzed, it was noticed that, 3 groups depicted *understanding the pattern/chance/algorithm*, whereas the majority, 8 out of 12 groups showed *using language or tools;* however, 5 groups included *problem solving or modeling*, and 5 groups showed *human endeavor* in addition to other codes, just like in the conception of science.

In the analysis of final posters, it was observed that, two groups, one of which was the same group as in the initial posters, didn't show any specific codes, yet a more integrated model. Six groups used only one code, which was *using language or tools*, three groups depicted *understanding the pattern/chance/algorithm*, only 1 group included *problem solving or modeling*, and finally 3 groups showed *human endeavor* with the other codes. Even though the number groups showed the codes for *understanding pattern/chance/algorithm* and the *language or tools* didn't change, from initial to final poster as summarized in Table 3, *language or tools* was the most popular code as it was shown by almost all the groups (9 out of 10) who represented their conceptions of mathematics.

Table 3. Number of groups represented various conceptions of ‘mathematics’ in the initial and final posters

Conceptions of ‘mathematics’ represented in the posters	Number of groups showed in the initial posters (n)	Number of groups showed in the final posters (n)
Understanding pattern/chance/algorithm	3	3
Language or tools	9	9
Problem solving or modeling	5	1
Human endeavor	5	3

Similar to the conception of science, the conception of mathematics were represented by giving less detail and information compared to the initial posters. Figure 6. is an example, depicted by Group W, showing the change in conceptions of mathematics from (a) initial to (b) final posters. In the initial poster, mathematics was represented either by drawing or text, by *using language or tools*, *problem solving or modeling*, and *human endeavor*, whereas in the final poster it was only shown by symbols of arithmetic, which was coded as *using language or tools*.



6(a) 6(b)

Figure 6. (a) Initial poster, (b) final poster of Group W.

Conceptions of ‘Technology’ Represented in the Initial and Final Posters

The analysis of initial and final posters with respect to conception of technology was based on the definition of technology as coded by *device*, *process*, and *human benefit*. The analysis of initial posters revealed that 4 out of 12 posters didn’t show any codes for technology, 4 of them included only one code, which was the *device*, 1 poster showed 2 codes and 2 posters had all three codes. The majority, 7 out of 12, of the posters depicted the code *device*, whereas three of them showed the *process*, and the code *human benefit* was observed only in 2 posters.

When the final posters were analyzed, it was observed that, two posters, who were the same as the initial ones, did not include any specific details for the code of technology. Seven posters used only the single code of *device*, two posters included two codes, *device*, and the *process*, and only one poster showed all three codes. All in all, in the final posters, *all* the posters who showed a code, 10 out of 12, included the code of *device*, three of them used the code of *process*, and only 1 poster used the code of *human benefit*. Table 4 summarizes the number of groups who represented different conceptions of ‘technology’ in the initial and final posters

Table 4. Number of groups represented various conceptions of ‘technology’ in the initial and final posters

Conceptions of ‘technology’ represented in the posters	Number of groups showed in the initial posters (n)	Number of groups showed in the final posters (n)
Device	8	10
Process	3	3
Human benefit	2	1

The trend of showing less details as going along from initial to final posters was also seen for the conception of technology and the *device* aspect of technology gained prime importance. Figure 7 is an example, created by Group V, showing the change in conceptions of technology from (a) initial to (b) final posters. In the initial poster, technology was represented by the picture of robot, coded as *device*, text of ‘problem solving’ inside the Venn diagram, coded as *process, and* finally the symbol of sun, coded as the *human benefit.* In the final poster, technology was represented by the pictures of laptop computer, robot, programming codes, internet, and cell phone which were all coded as *device*.

7(a) 7(b)

Figure 7. (a) Initial poster, (b) final poster of Group V

Conceptions of ‘Engineering’ Represented in the Initial and Final Posters

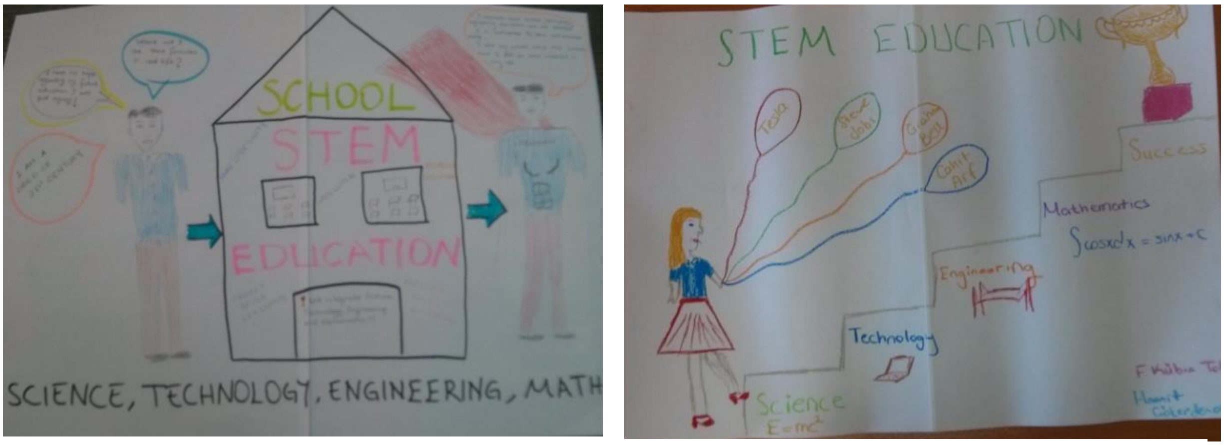
The analyses of initial and final posters for the conceptions of engineering were done with respect to the codes taken from the definition of engineering; these codes included *human benefit (purpose), product/structures, process (design and construction),* and *human endeavor*. The analysis of initial posters revealed that 4 groups didn’t include any codes for technology, 4 groups showed a single code, which was the *process*, 2 posters included two kinds of codes and only 1 poster had three codes. It was observed that, all the groups who used one kind of code, 7 out of 12, included the code of *process* either in the form of design or constructing, 3 groups showed the structure, and only one group had a code for *human endeavor*. Interestingly, none of the posters showed the code of *human benefit* neither in the initial nor in the final posters.

The analysis of final posters for the conception of technology showed that two groups, who were the same two determined in the initial analysis, didn’t use any codes to represent engineering. Six groups used only one type of code, 3 groups included two types of codes, and only 1 group depicted three codes. All in all, while 8 out of 12 groups indicated the *process*, whereas 3 groups depicted the *structure* aspect of engineering. On the other hand, *human endeavor* aspect of engineering was represented by 4 groups suggesting that the emphasis on human aspect increased from initial to final posters. As it is seen in Table 5, except the code of *human endeavor*, the number of groups who represented the codes for *product/structures, process (design and construction)* for the conceptions of ‘engineering’ in the initial and final posters didn’t change.

Table 5. Number of groups represented various conceptions of ‘engineering’ in the initial and final posters

Conceptions of ‘engineering’ represented in the posters	Number of groups showed in the initial posters (n)	Number of groups showed in the final posters (n)
Human benefit (purpose)	0	0
Product or structures	3	3
Process (design & construction)	8	8
Human endeavor	1	4

The last but not least, the conceptions of technology mostly included the device, even without human, whereas the conceptions of engineering mostly included the *process*, equally with or without human. Figure 8 is an example, depicted by Group T, showing the change in conceptions of engineering from (a) initial to (b) final posters. In the initial poster, engineering was not represented by any specific code, whereas in the final poster it was represented by the pictures of a bridge which was coded as *structure* and the name of Tesla, which was coded as *human endeavor*.



8(a) 8(b)

Figure 8. (a) Initial poster, (b) final poster of Group T.

Conclusion and Discussion

In this study, the pre-service chemistry and mathematics teachers participated in the CLT-STEM Module during their corresponding teaching methods courses. Analysis of their STEM images depicted in initial and final posters revealed their conceptions of STEM integration, purpose of STEM education, and conceptions on the four disciplines of STEM. The change in the conceptions of STEM integration levels can be summarized as increase in seven groups, no change in three groups and decrease in three groups. The levels of conceptions of STEM integration used for analysis of posters were ranging from *disconnected* to the highest level *integrated*. Since CLT-STEM module was prepared with STEM definition of *infusion*, an increase in majority of the groups' STEM conception level was expected. In addition to changes of individual groups, a change in the whole group is also important to note. When all participating preservice teachers considered, most of the initial posters were coded as either disconnected or connected. In other words, before CLT-STEM module, preservice teachers' conception was based on the reading given to them and they were at most recognizing the connection between these areas. Due to infusion nature of CLT-STEM, they were able to experience STEM activities without much separation. Nature of CLT-STEM Module may explain conceptions of STEM integration codes of *complimentary* and *integrated* levels being majority in the final posters. These two higher levels categorized in a way to depict STEM areas to work together, collaboratively to solve complex problems, and to handle real-world issues.

A close look at groups whose posters showed no change or decrease in terms of STEM conception, revealed a change in the purpose of STEM education. The posters with decrease in STEM conception, the focus of final posters were on purpose of STEM education to be effective learning of STEM areas. Therefore, it may be concluded that when there is a negative change in conceptions of STEM integration, participants were trying to put emphasis on the purpose of STEM education for effective instruction in their final posters. Analysis of other groups' representation of purpose of STEM education also indicated a paradigm shift. As the participants were focusing on the definition of STEM before the CLT-STEM module, they started to think more about implementing STEM in teaching. They mostly discussed the goal of STEM education in final posters. This conclusion was also encouraging for CLT-STEM Module which focused on STEM education to teach important topics such as nanotechnology, and functions.

When the initial and final posters were analyzed with respect to the pre-determined codes coming from the definition of each subject field, generally a decrease in the number of codes was observed. Specifically, when representing the conceptions of science in the initial posters 2 groups had only one code, whereas in the final posters this number increased to 5. Similarly, for the conceptions of mathematics, , in the initial posters one group used only one code, and in the final posters this number increased to 6. The number of groups using single code in their initial and final posters also changed from 4 to 7, respectively. For the conception of engineering, again, from initial to final posters the number of groups using only one code increased from 4 to 6. It could be claimed that as the preservice teachers completed the CLT-STEM Module they started to represent their conceptions of each field with less details. This result is also consistent with the STEM integration conceptions as the majority of the students moved towards the higher end of the continuum revealing that they have started to see the big picture of the STEM instead of compartmentalizing each piece.

As the pre-service teachers started to include less detail for each subject field, they had a tendency to show one specific symbol representing that field such as, an erlen flask for science, the number pi for mathematics, a laptop computer for technology, and a gear for engineering. Interestingly these symbols were the representative examples of most commonly used code both in the final posters. For instance, the erlen flask was coded as the representation of *scientific inquiry – tools* was used by 6 of the groups in the posters, the number π which was coded as *language or tools* for the conception of mathematics, was shown by 9 groups, the laptop computer which was coded as the *device*, was shown by 10 groups, and finally the gear which was coded as the representation of *process (design & construction)* was shown by 8 of the groups in the final posters. In that sense, there observed a decrease in the number of codes for *process* for science, *modeling* for mathematics, and increase in the number codes representing *tools* for science, and *device* for technology. This result was also consistent with the finding for STEM conceptions or the purpose of STEM, as they refine their conceptions towards a more coherent conception as they include less but the most representing element for them.

Considering the codes derived from their definition, the natures of science and mathematics, and that of technology and engineering were found to be similar. Yet, participants were more likely to show *understanding natural world* for the conceptions of science, they were less likely to use *understanding pattern/chance/algorithm* for the conceptions of mathematics as opposed to their frequent use of *language or tools*. This difference might have stemmed from the differences in the emphasis had put on the science and mathematics classes they had taken. For instance, in the science classes they might have experienced more on understanding the natural world and scientific inquiry, whereas in mathematics classes they might have more experience with using mathematical language and tools. Furthermore, even though the codes for technology and engineering seemed to be similar, *device*, and *process* were the most commonly used codes for technology and engineering, respectively. This result might have been observed due to the differences between the practical applications that they experience in daily life such that using a laptop computer on a daily basis, whereas their image of engineering might have been developed through media.

STEM education, as a growing, nurturing and uniting field, is particularly important for preservice teacher education because they will be the teachers of the next generation. Thus many studies have been conducted and their impacts have been evaluated. It has been reported that preservice science teachers who received particular STEM education improved their content knowledge (Pinnell et al. (2013, Yildirim and Altun, 2015), decision making and science process skills (Bozkurt, 2014), and perceptions of STEM teaching efficacy, inquiry implementation, and comfort with teaching STEM (Nadelson et al.(2012). The findings of this study are said to be in line with the findings of previous studies in terms of improving preservice science and mathematics teachers' STEM conceptions.

All in all, the study reported in this article showed that preservice teachers conceptions of STEM integration, as well that for each subject area changed towards a more integrated view as they complete CLT-STEM Module. The findings of this study encourage implementing STEM education in preservice science and mathematics teacher education. Further analysis of preservice teachers' experiences may reveal nature of their learning during such a program (Aslan-Tutak & Akaygun, 2015). There may be a follow-up study with participating preservice teachers in order to examine how they enact their knowledge of STEM education.

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Author Information

Sevil Akaygun
Department of Secondary School Science and Mathematics Education, Bogazici University, 34342, Istanbul, Turkey
Contact e-mail: sevil.akaygun@boun.edu.tr

Fatma Aslan-Tutak
Department of Secondary School Science and Mathematics Education, Bogazici University, 34342, Istanbul, Turkey