The Functions of each Discipline in STEM Practices

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Introduction

Establishing connections between different disciplines have received increased attention in business world. Individuals from different professions, for instance a computer engineer, an industrial engineer, a physicist and a business manager have been coming together to organize a team when carrying on a project in various areas. Without teamworks, individuals can also face some real world problems that require various disciplines to be used in order to make a decision or solve the complex problems (Mansilla, 2005). However, they may have difficulty in integrating their knowledge and skills acquired in a meaningful way since the mathematics, science, history and other disciplines are considered as isolated subjects in schools although they are related to each other in reality, which leads to the need to an integrated education (Berland, 2013). At this point, it is important to differentiate the terms of multidisciplinary approach and interdisciplinary approach. *Multidisciplinary* has been defined as individuals from different disciplines working independently on different aspects of a project (Mallon, & Burnton, 2005) or subject-specific concepts and skills are learned separately in each discipline and students are expected to connect the content, taught in different classrooms, on their own (Thibaut, et al., 2018). *Interdisciplinary* refers to the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement in ways that would have been unlikely through single disciplinary means (Mansilla, 2005). So, the integration attempts in schools have increased in order to raise qualitative and productive individuals by providing learning environments where students gain experience on integrating different disciplines and making practical applications of the abstract theories in mathematics and science (Carlson, & Sullivan, 1999; Estapa, & Tank, 2017; Kaleci, & Korkmaz, 2018; Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, & Kimmel, 2010; Stohlmann, Moore, McClelland, & Roehrig, 2011). In this sense, STEM that is the acronym of science, technology, engineering and mathematics disciplines has emerged as an integrated education and become widespread in the K-12 education (Johnson, 2013).

The integration of STEM disciplines in education can traced back to the integration of two disciplines to make teaching better. There exist several efforts about integrating technology, history and engineering into mathematics and science instructions and integrating mathematics and science (Alpaslan,& Haser, 2012; Furner, & Kumar, 2007; Khosrow-Pour, Clarke, Becker, & Anttiroiko, 2015; Ondes, & Ciltas, 2018). Yet, according to STEM Roadmap book (as cited in English, 2017), STEM education is not simply integrating two disciplines for teaching something that many educators are already doing this. By contrast, STEM is a holistic approach that links the disciplines so the learning becomes connected, focused, meaningful and relevant to learners as an interdisciplinary curriculum (Smith & Karr-Kidwell, 2000). In addition to these, Johnson (2013) defines STEM as "*an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21st century interdisciplinary themes and skills*".

In addition to the various definitions of the STEM education that is still on the development process, there is no common understanding of STEM integration on practices (English, 2017; Holmlund, Lesseig, & Slavit, 2018; Johnson, 2013; Pellas, Kazanidis, Konstantinou, & Georgiou, 2017; Stohlmann, 2018; Thibaut, et al., 2018). In some researches, it can be seen that mathematics and science are on the central when technology and engineering are considered as the supporting vehicle (Corlu, Capraro, & Capraro, 2014; Rockland, et al., 2010; Stohlmann, 201), while in some researches the priority were given to science and engineering rather than mathematics and technology (Ring-Whalen, Dare, Roehrig, Titu, & Crotty, 2018; So, Zhan, Chow & Leung, 2017). At this point, it is important to define two main models for the implementation of the STEM, which are content and context integration. *Content integration* focuses on the merging of more than one discipline into a single curricular activity or unit to highlight "big ideas" from multiple content areas, while *context integration* is putting one discipline into the center and teaching it in a meaningful way by selecting relevant contexts from other disciplines without ignoring the unique characteristics, depth, and rigor of the main discipline (Thibaut, et al., 2018).

Although STEM implementations vary with different models, perspectives or frameworks addressed, they mostly start from a problem, follow engineering design process and end with a product as a solution of the problem. At the beginning, the problems introduced should be open-ended, real-world, authentic and ill-structured in the context of meaningful, engaging and motivating (Holmlund, et al., 2018; Thibaut, et al., 2018). Since the structure of these problems are similar to the mathematical modeling problems, it can be seen that Model Eliciting Activities (MEAs) which have multiple entry and exit points within the client-driven, real life context have been using in science, mathematics and engineering lessons (Moore, 2008). MEAs, especially engineering design based MEAs can be considered as a bridge for STEM integration since they enables to enhancing the constructed mathematical representations/

models as equation, graph and diagram at the end to hands-on products (Baker, & Galanti, 2017; Baker, Galanti, & Birkhead, 2017; Hamilton, Lesh, Lester, & Brilleslyper, 2008; Kertil, & Gurel, 2016; Stohlmann, 2018). During the process of STEM practices, engineering design process (EDP) including the iterative steps of asking, imagining, planning, creating and improving is used (DiFrancesca, Lee, & McIntyre, 2014; English, 2017; Hamilton, et al., 2008; Hill-Cunningham, Mott, & Hunt, 2018). The definitions of the each EDP steps are in the following:

1. Ask: The problem is defined and constraints are identified
2. Imagine: The best idea is chosen after the brainstorming of the ideas
3. Plan: A model or diagram is drawn and materials are collected
4. Create: The plan is followed and tested
5. Improve: Possible improvements are discussed and all steps are repeated

At the end of the STEM practices, prototypes, products or models were designed and constructed. Yet, it is important to address that creating something or designing models does not always mean doing STEM products. Although mathematics/science principles and concepts can be implicitly used in construction of any physical/digital models in Do It Yourself (DIY), thinkering/maker activities, hacking, creative arts and creation with client designed without math/science based knowledge, it is important to applying math and science concepts/principles when designing or constructing a prototype in STEM challenge (Berland, 2013; Marshall, & Harron, 2018). Since engineering represents the application of science and mathematics concepts to meet human needs and make life better for them, engineering design provides students an opportunity to use math and science concepts in real life to solve the problem (Carlson, & Sullivan, 1999; Chien, & Chu, 2018; Harrison, 2011; National Research Council, 2010; Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, & Kimmel, 2010). Thus, EDP is not just the process of constructing products through hands-on activities as it plays an important role as connecting glue for STEM integration (Brophy, Klein, Portsmore, & Rogers, 2008; Stohlmann, 2018).

By the growing and developing STEM literature, there is still no common agreement on the implementations of STEM activities. With respect to the content and context integration, it can be seen that science, technology, engineering and mathematics are used as a main focus, supporting tool or context in STEM practices, which are the general categorization of their usage (Coad, 2016; Corlu, Capraro, & Capraro, 2014; Stohlmann, 2018; Stohlmann, et al., 2011). However, more detailed categorization can be seen in the integration of technology into instructions since the classification includes different purposes of the supporting tool as communication, exploration, evaluation, management and motivation (Sherman, 2014). In this sense, the functions of each STEM discipline explicitly in practices can be identified. On the other hand, there exist some claims that T, M or E do not receive same attention as S (Fitzallen, 2015; Guzey, Moore, & Harwell, 2016; Harrison, 2011; Rockland, et al., 2010; Stohlmann, 2018). So, it is important to address in which ways STEM disciplines are used in integrated applications. As a result, researchers, educators and teachers from different fields can choose the best STEM integration from multiple ways with respect to their purposes. Also, it can offer a framework that illustrates the various usages of the disciplines in integrated activities and provide an opportunity to see the different approaches and improve implementation plan in a more constructivist way. In this sense, the aim of the study is to identify the function of each STEM discipline in integrated practices. So, the research questions are as follows:

- In which roles science from the components of STEM is used in integrated STEM education?
- In which roles technology from the components of STEM is used in integrated STEM education?
- In which roles engineering from the components of STEM is used in integrated STEM education?
- In which roles mathematics from the components of STEM is used in integrated STEM education?

Meta-synthesis was used as a research design in this study. Meta-synthesis is the systematic synthesis of the qualitative studies conducted on the same subject through a process of identifying patterns and forming common themes by comparing their similarities and differences with a critical insight and a holistic approach (Calık and Sözbilir, 2014; Glesne, 2013). Since the aim of the study is to identify the roles of each component in STEM, it is appropriate to use meta-synthesis that enables to examine the previous studies on STEM critically; compare the roles of each discipline in STEM by systematically identifying the similarities and differences of them and provide a framework involving the common categories of the each role.

Since STEM is the abbreviation of science, technology, engineering and mathematics, the keywords are determined as “stem”, “stem education”, “stem integration”, “integrated stem”, “science technology engineering mathematics”, “model eliciting activities and stem", "integrated education", "stem approaches", "mathematics and engineering", "engineering integration in stem", "science and mathematics integration", "technology integration", "stem learning", "stem implementation".

By using these keywords, articles were searched in the databases of Web of Science, ERIC and Google Scholar. At this point, the abstracts of the articles were examined whether they are appropriate for the purpose of this meta-synthesis study or not. Here, the quantitative studies (the effects of STEM in students' achievement, attitudes etc.) and phenomenological studies (only focus on the views of participants) were extracted. The papers contain the examination of the application and process of the activity were collected in order to analyse the usage of the disciplines. After finding appropriate studies, those that use STEM disciplines in different ways were selected to synthesise various functions of them with respect to our purpose. Briefly, they are examined in detail according to the inclusion and exclusion criteria given below. At this point, the main criteria is that the article should have contain the description of an activity covering more than one STEM disciplines in order to identify the roles of science, technology, engineering and mathematics.

Exclusion Criteria:

- Quantitative researches (studies having only quantitative results)
- Researches focusing only the effect of STEM on students' achievement/ motivation/skills without presenting STEM activities in the process
- Researches focusing only the investigation of the participants' views/attitudes/ perceptions qualitatively
- Reviews/Meta analysis/ Concept Analysis that discuss the concepts without presenting an application about STEM

Inclusion Criteria:

- Researches including the description of an activity that is related to more than one STEM disciplines (S-M, E-M-T, S-T-E-M, S-E-T etc.)
- Researches having different perspectives on STEM integration practices

At the end of the application of the exclusion and inclusion criteria, researches were analyzed by considering the roles of STEM components. Then, researches offering variety for the components' roles were selected since the sample of the meta-synthesis study can be determined purposely. Thus, 15 researches were obtained as given in Table 1. (Aquino, Caliguid, Buan, Magsayod, & Lahoylahoy, 2018; Baker & Galanti, 2017;

Baker, Galanti, & Birkhead, 2017; Berland, 2013; Bryant-Davis, & Hardin, 2013; Ceylan & Ozdilek, 2015; Chien & Chu, 2018; English, 2017; English & Mousoulides, 2015; Kern, Howard, Brasch, Fiedler & Cadwell , 2015; Kertil & Gurel, 2016; Nemorin & Selwyn, 2016; Ring-Whalen, Dare, Roehrig, Titu & Crotty, 2018; So, Zhan, Chow & Leung, 2018; Sumrall, 2015).

Table 1. The Sample of the Researches and Their Demographic Features

Authors	Primary Focus	Activity Names
Aquino, et al., 2018	Engineering	Rocket Building
Baker and Galanti, 2017	Mathematics	Survivor/Packing a Truck/ Creating a Mosaic/A day at the Zoo
Baker, et al., 2017	Mathematics	Pelican Colonies
Berland, 2013	Engineering	Pinhole to Pixels
Bryant-Davis and Hardin, 2013	Engineering	Rocket Launches/ Card Building/ Simulators/ Egg Drop/ Skyscraper
Ceylan and Ozdilek, 2015	Science	Acids and Basis
Chien and Chu, 2018	Engineering	Racing Cars
English, 2017	Mathematics & Engineering	Similar findings related to the codes
English and Mousoulides, 2015	Engineering	Bridge Design
Kern, et al., 2015	Engineering	The Fish Weir
Kertil and Gurel, 2016	Mathematics & Engineering	Rocket Project/The Cassette Player MEA
Nemorin and Selwyn, 2016	Engineering	Race Car Design
Ring-Whalen, et al., 2018	Engineering	Soccer Stadium / Cross Pollination of GMOs / Improving the Mechanical Claw
So, et al.,, 2018	Science	Homemade food waste enzyme cleanser/ Combustion efficiency
Sumrall, 2015	Engineering	Recycling Metallic Elements

Since the present study seeks to identify the characteristics of each discipline in STEM, the main categories have been already formed as science, technology, engineering and mathematics. However, the codes representing the different roles were constructed by constantly comparing-contrasting the roles of the science, technology, engineering and mathematics in each research. The code names are chosen from the literature to make them familiar and they are decided by the agreement of the authors with an expert opinion. Furthermore, some activities included in researches have more than one role for one discipline; hence they were assigned under the each code that they match up with. Also, in coding process, it was beneficial to use the explanations or discussions about the activities, processes or implementation practices in studies if exists when making classification of the research and deciding which code they belong to.

The findings obtained through the analysis of the researches defined were presented under four sections that are related to the research questions focusing on the different usage forms of the disciplines in implementations.

The Roles of "S" in STEM

Scientific knowledge, principles and concepts can be used in STEM based approaches, which gives an opportunity for linking and applying science in real life. Also, the science discipline has been considered as main focus in content integrated STEM education. However, there exist many ways of integrating science with different disciplines, and hence its role has been changing in different implementations. According to the examined articles in this study, science plays roles as a tool for providing information, as a tool for contextualizing the problem situation and as a context for applying science process skills (SPS) and scientific inquiry as given in Table 2.

Table 2. The Roles of Science in STEM Education

	Science	Descriptions
As a tool	For providing information	Scientific knowledge is necessary for constructing a model as a solution of the problem or completing the activity.
	For contextualizing the problem situation	Scientific ideas are covered in problem situation to make them more meaningful for real life.
As a context for applying science process skills (SPS) and scientific inquiry		SPS and scientific inquiry used within the science standards and curriculum objectives in the integrated implementations.

The descriptions of the each role as follows:

- *Science as a tool for providing information* refers to that scientific knowledge is necessary for constructing a model as a solution of the problem or completing the activity. In other words, activities require using scientific principles and concepts that are already known and making research for unknown scientific knowledge and for further information. So, it is observed that science has been using in the part of extending information. For example, when recycling metals, the information of the properties and qualities of the metals; when building a rocket, the principle of Newton's Law 3; when constructing ph metre, the information of ph degrees in acid and bases are required.
- *Science as a tool for contextualizing the problem situation* refers to that scientific ideas are covered in problem situation to make them more meaningful for real life. Mathematical problems can be extended by integrating science ideas as they

are not isolated in real world situations. For instance, the model eliciting activity that focuses on mathematics and does not focus on the scientific principles includes scientific information as speed and velocity in the context of problem.

- *Science as a context for applying science process skills (SPS) and scientific inquiry* refers to that science process skills (e.g., posing questions, planning investigations, analysing and interpreting data, providing explanations, and making predictions) and scientific inquiry used within the science standards and curriculum objectives in the integrated implementations. It was considered that science is used in activities when analysing and interpreting data since scientific inquiry and science process skills provide an environment for students to think like a scientist.

The Roles of “T” in STEM

As mentioned in literature review, technology can be used as a goal and as management tool, communication tool, motivational tool and cognitive tool for discovery in teaching. By taking into account them, technology usage in STEM related activities was categorized by examining the researches. The findings indicates that technology plays roles as a supporting tool for researching, collecting data, analysing data, graphing data, sketching 3D models, creating simulation and animation video, checking data and producing prototypes, and technology plays a role as a practical context for end product as given in Table 3.

The descriptions of the each role as follows:

- *Technology as a supporting tool for researching* refers to that the Internet, presentations, informative videos are used as a tool when gathering information that is required in an activity.
- *Technology as a supporting tool for collecting data* refers to that Internet or other useful programs are used when collecting data from real life situations that is required for an activity.
- *Technology as a supporting tool for analysing data* refers to that analysing programs are used as a tool when collected, existed data needs to be analysed.
- *Technology as a supporting tool for graphing data* refers to that some software programs are used to represent the data in terms of graph, table and figures.
- *Technology as a supporting tool for sketching 3D models* refers to that some

dynamic geometry software and sketching programs are used to design 3D model that is required to be constructed in activity with appropriate sizes.

- *Technology as a supporting tool for creating simulation and animation video* refers to that some programs are used to make simulations and design an animation video within the activity.

- *Technology as a supporting tool for checking data* refers to that some technological devices and software programs are used to test the solution and measure the quantities that are found in the process of activity.

- *Technology as a supporting tool for producing prototypes* refers to that vehicles like LEGO, maker kits, robots, 3D printer and hands-on materials are used to make hands-on constructions that enable to design a prototype.

- *Technology as a practical context for end-product* refers to that

produced products, crafts and designed models at the end of the activities are considered as technological tools.

Table 3. The roles of Technology in STEM Education

Technology		Descriptions
As a supporting tool	For researching	Technology is used when gathering information that is required in an activity.
	For collecting data	Technology is used when collecting data from real life situations that is required for an activity.
	For analysing data	Technology is used when collected, existed data needs to be analysed.
	For graphing data	Technology is used when representing the data in different forms.
	For sketching 3D models	Technology is used when designing 3D model that is required to be constructed in activity with appropriate sizes.
	For creating simulation/animation video	Technology is used when making simulations and designing an animation video within the activity.
	For checking data	Technology is used when testing the solution and measuring the quantities.
	For producing prototypes	Technology is used when designing hands-on constructions.
As a practical context for end product		Produced products, crafts and designed models at the end of the activities are considered as technological tools.

The Roles of "E" in STEM

According to the findings obtained from identified researches, there exist different types of engineering integration into activities. As stated in Table 4., engineering has roles as a tool for application of math/science knowledge, as a tool for generating hands-on solution and as a context for application of engineering design process.

Table 4. The Roles of Engineering in STEM Education

Engineering	Descriptions
As a tool for application of science/math knowledge	Observing, testing and learning the scientific/mathematical knowledge.
As a tool for generating hands-on solution	Designing, prototyping and modelling products for the solution of real life problem.
As a context for application of engineering design process	Applying the iterative steps of asking, imagining, planning, creating and improving.

The explanations of the each role as follows:

- *Engineering as a tool for application of science/math knowledge* refers to that science and math concepts, principles are applied in real life by the help of engineering which offer an opportunity to observe, test and learn the scientific/ mathematical knowledge (formulas, laws, etc.).
- *Engineering as a tool for generating hands-on solution* refers to that engineering enables to find solutions to real life problems by designing, prototyping, modelling a craft or product in the range of hands-on practices.
- *Engineering as a context for application of engineering design process* refers to that engineering provides an environment for using engineering design process in activities by applying the iterative steps of asking, imagining, planning, creating and improving.

The Roles of "M" in STEM

The findings that were obtained from examined researches by considering the mathematics component were presented in Table 5. According to them, mathematics has roles as a supporting tool for calculation, measurement, data analysing, data representation and variable analysing; and a context for the application of mathematical modelling process; quantitative and proportional reasoning; and geometry.

The explanations of the each role as follows:

- *Mathematics as a supporting tool for calculation* refers that mathematics is used when using number operations and algebra to work out the answer required in the activity process. These calculations include simple operations like addition, subtraction, multiplication and division of natural, rational numbers and integers or advanced operations like differentiation, trigonometry (sin,cos etc.).

- *Mathematics as a supporting tool for measurement* refers that mathematics is used when measuring *angles,* length, area and volume of the objects or figures.
- *Mathematics as a supporting tool for data analysing* refers that mathematics is used in the process of examining, transforming and arranging raw data for inferring information from it.
- *Mathematics as a supporting tool for data representation* refers that mathematics is used when demonstrating data in algebraic expressions and the visual forms like tables, graphs and models.
- *Mathematics as a supporting tool for variable analysing* refers that mathematics is used when interpreting the variables in the formulas and equations.
- *Mathematics as a context for the application of mathematical modelling process* refers that mathematics is used within the context of model eliciting that provides an environment to solve problems in mathematics world by following the iterative process of mathematizing, interpreting, verifying, revising and generalizing the mathematical model.
- *Mathematics as a context for the application of quantitative & proportional reasoning* refers that mathematics is used within the context of quantitative reasoning that enables converting verbal, graphical, numeric and symbolic representations to each other; interpreting measured data and models by connecting it to physical phenomena; and proportional reasoning that enables making comparisons between quantities in multiplicative terms in the range of problem situation.
- *Mathematics as a context for application of geometry* refers that mathematics is used when working with hands-on physical objects and digital designs in the context of geometry (circles, geometric shapes, triangles, polygons, etc.). It is also related to the art (A in STEAM).

Table 5. The Roles of Mathematics in STEM

Mathematics		Descriptions
As a supporting tool	For Calculation	When number operations and algebra to work out the answer required.
	For Measurement	When measuring length, area and volume of the objects or figures.
	For Data Analysing	The process of examining, transforming and arranging raw data for inferring information from it
	For Data Representation	When demonstrating data in algebraic expressions and the visual forms like tables, graphs and models.
	For variable analysing	When interpreting the variables in the formulas and equations.
As a context	For the application of mathematical modelling process	Model eliciting that provides an environment to solve problems in mathematics world by following the iterative process.
	For the application of quantitative & proportional reasoning	Converting verbal, graphical, numeric and symbolic representations to each other; interpreting measured data and models by connecting it to physical phenomena; making comparisons between quantities in multiplicative terms.
	For the application of geometry	When working with hands-on physical objects and digital designs in the context of geometry

The nature of the real life problems are composed of different disciplines, which leads to integrating various disciplines to each other in order to raise qualitative and productive individuals who can apply the abstract knowledge of science, technology, mathematics for solving problems and meeting their needs. The widespread integration approach in education is STEM (Science, Technology, Engineering, Mathematics) which can be implemented by using two main models as content and context integration. However, there is still no common agreement on the implementations of STEM activities due to different perspectives, approaches, and models about the integration, which causes to use each discipline in STEM differently. Thus, this study aiming to identify the roles of the disciplines in STEM was conducted by synthesizing of 15 researches containing STEM related practices and explanations inside. The findings of the current study were presented under four categories corresponding to the research questions as the roles of S, T, E and M in STEM.

The first research question of the study is regard to the identification of the roles of science in integrated STEM education. According to the findings, science plays roles as a tool for providing information, as a tool for contextualizing the problem situation and as a context for applying science process skills (SPS) and scientific inquiry. The findings are consistent with the idea that science is an integral part of STEM integration and science is mostly positioned as central point rather than mathematics, technology and engineering (Corlu, et.al., 2014; Rockland, et al., 2010; Ring-Whalen, et al., 2018; So, et al., 2017 Stohlmann, 2018). This may be result from the fact that scientific knowledge, principles and concepts are related to the real life contexts and constructed products contain scientific knowledge inside in some way. When considering the beginning of the STEM related activities that generally start with a problem from real life context, the problem situations contain the discipline of science as explicitly or implicitly since it cannot be considered as an isolated discipline from the real world (Baker, et al., 2017; Holmlund, et al., 2018; Kern, 2015; Kertil, & Gurel, 2016; Sumrall, 2015; Thibaut, et al., 2018) That means, scientific ideas may be covered in problems in order to make them more meaningful for students, or scientific knowledge may appear explicitly in problems. So, the possible explanation of this might be that science can be used as a tool for contextualizing the problem situation for making sense of them. When considering the end of the STEM related activities that generally require designing a model for the solution of the problem addressed, scientific knowledge is used in some way when designing and constructing products, models or crafts (Carlson, & Sullivan, 1999; Chien, & Chu, 2018; Harrison, 2011; Rockland, et al., 2010; Marshall, & Harron, 2018). This may be result from the fact that scientific knowledge takes place in a wide range of interval from determining the materials by considering the properties of them to building products by considering the physical phenomena (Aquino, et al., 2018; Kertil, & Gurel, 2016; Sumrall, 2015). Therefore, it can be inferred that science can be used as a tool for providing information to complete the activity. When considering the process of the STEM related activities that use the engineering design process (asking, imagining, planning, creating and improving), it can be seen that scientific process skills and scientific inquiry may be involved in the process. This may be result from the fact that both engineering design and scientific process have related iterative steps in common (Dillivan, & Dillivan, 2014; Rockland, et al., 2010; Kelley, 2010; Koretsky, 2018; Lewis, 2006). Questions can be posed, investigations can be planned, data can be analysed and interpreted, possible explanations can be presented and predictions can be done in which a problem and constraints are defined, the best solution is chosen among possible solutions, model is drawn, materials are collected, the plan was implemented, prototype is built and tested, improvements are done if needed. So, science can be used as a context for applying science process skills (SPS) and scientific inquiry during the activity.

The second research question of the study is about the identification of the roles of technology in integrated STEM education. Based on the findings it was observed that technology has different roles as a supporting tool for researching, collecting data, analysing data, graphing data, sketching 3D models, creating simulations and animation videos, checking data and producing prototypes, and technology plays a role as a practical context for the end product. These findings are consistent with the previous study that technology can be used in different purposes as a goal and as tool for management, communication, motivational, and cognitive (exploration) in terms of the diversity of the usages (Sherman, 2014). This may be result from the fact that technology can make the procedures easier and possible. So, technological software programs and technological tools can be used as an assistant and supporting tool when researching something on Internet to get information about the problem, materials or solutions; collecting data for the solution of the problem; analysing data to see the patterns and make inferences; graphing data to make conclusion from the representations that seem more systematic; sketching 3D models besides 2D or paper-pencil drawings to prototype the design before constructed; creating and designing simulations and animation video to present the solution of the problem; checking data to control the measurements when determining their appropriateness; and producing prototypes to demonstrate the model as a solution. In other words, technology can take place in every part of the procedure from searching about the problem to designing a model. Also, the finding that the technology is used as a practical context for the end product may be results from the fact that produced products, crafts and designed models at the end of the activities can be considered as technological tools, which can be supported by the idea that technology also means innovations such as pencils, aspirin and microscopes that used for various types of human activities such as farming, agriculture, manufacturing, industrial, military, and so on (National Research Council, 2010).

The third research question of the study is about the identification of the roles of engineering in integrated STEM education. Based on the findings, engineering has roles as a tool for application of math/science knowledge, as a tool for generating hands-on solution and as a context for application of engineering design process. The findings are parallel with the previous studies that integrate the engineering into math, science and engineering courses to show that it provides an environment for applying theoretical knowledge in real life to allow students make sense of them. Also, as seen in the literature, at the end of the engineering design-based and project-based instructions, students are expected to construct, build or design a craft, which consistent with the idea of engineering as a tool for generating hands-on solution (Carlson, & Sullivan, 1999;

Chien, & Chu, 2018; Harrison, 2011; Rockland, et al., 2010). The possible explanation of this may be that engineers try to meet human needs and make their lives better by designing products. However, constructing something is not always making engineering since without scientific/mathematical knowledge it can be any craft like DIY and puzzle robots that depend on only creativity or guidance of someone (Marshall, & Harron, 2018). At this point, it is important to implement engineering design process which enables STEM based activities to be integrated with engineering and allow students to think like an engineer (Berland, 2013; Brophy, et al., 2008; Stohlmann, 2018). This may be result in that engineering is used as a context for applying engineering design process in STEM integrated practices since without systematic process creating something by trial and error cannot be related to engineering.

The forth research question of the study is related the identification of the roles of mathematics in integrated STEM education. The findings indicate that mathematics has roles as a supporting tool for calculation, measurement, data analysing, data representation and variable analysing; and a context for the application of mathematical modelling process; quantitative and proportional reasoning; and geometry. The results are consistent with the studies claimed that mathematics within STEM has not received the focus it deserves in integrated practices although the theoretical knowledge in mathematics can find an application area by STEM (Berland, 2013; Stohlmann, 2018**).** Also, it was stated that mathematics has already been using in science courses in the terms of calculation, graphing data, analysing variables and quantitative reasoning. The possible explanation of that may be that science and math are connected to each other since science requires using such types of mathematical processes when dealing with problems (Moore, 2008). However, it can be seen that mathematics supports science and other disciplines when making calculations, measuring *angles,* length, area and volume of the objects, analysing the given data, converting the findings into the different representations like graph, table and model, interpreting the formulas by considering the relationships of the variables and their coefficients, determining the sizes of the models to be drawn, constructing mathematical models like equations and graphs. Besides its supporting role, it was observed that mathematics enables to apply mathematical modelling process, quantitative and proportional reasoning and geometry (Koretsky, et al., 2018). This may be result from the fact that model eliciting activities that used in mathematics, engineering and science courses can build a bridge between the mathematics and STEM and allow to use mathematics more explicitly (Baker, & Galanti, 2017; Baker, et al., 2017; Hamilton, et al., 2008; Kertil, & Gurel, 2016; Stohlmann, 2018). Also, quantitative and proportional reasoning used implicitly in STEM have found an application environment in real life. Moreover, STEAM in which A (art) integrated may result in the using geometry as a context since the geometrical shapes, physical sizes are related to the geometry.

To sum up, integrated STEM practices can be different from one instruction to the other due the approaches and models followed. However, it can be seen that similarities and differences of the implementations exist and the roles of each discipline can be identified. At this point, it can be suggested that researchers, educators and teachers can consider the STEM roles determined in this study in order to develop better STEM activities and construct rubrics that assess the teachers' STEM instructions and their lesson plans. Also, the framework can be extended by examining the learning methods, materials used and the process followed.

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