The Effectiveness of a Hands-On Summer STEM Program in Developing Middle School Students' Design Thinking and Conceptual Understanding

Yasser Sayed Hassan (1)

Abstract

Science, technology, engineering, and mathematics (STEM) are the key to Egypt's global economic competitiveness. STEM education prepares skilled workforce, creates critical thinkers, increases science literacy, and enables the next generation of innovators. The purpose of the present study is to examine the effectiveness of a hands-on summer STEM program in developing middle school students' design thinking and conceptual understanding. To accomplish this purpose, a list of bases that should be taken into account while designing the summer STEM program was prepared. An instrument for design thinking and a test for conceptual understanding were developed. These instruments were administered to 28 students- who completed 8th grade- before and after participating in the summer STEM program. The findings showed that students' design thinking developed after the STEM program. On the other hand, the program increased the students' conceptual understanding. These findings indicate that the focus should be on the implementation of informal hands-on experiences to increase interest in STEM disciplines and improve the students' design thinking and conceptual understanding.

Keywords: Science, technology, engineering, and mathematics (STEM), hands-on, summer program, design thinking, conceptual understanding

Introduction

Large investments in science and technology during the 20th century led to the creation of new industries and smart

1 Lecturer at the Department of Curriculum and Instruction, Faculty of Education, Ain-Shams University, Roxy 11757, Cairo, Egypt.

companies. These changes require new skills for workers at all levels. Egyptians must decide whether they will be in the forefront of these changes or be left behind. Nations at all levels of development are now focusing on the capabilities required for building new jobs. At the core of almost every agenda is a focus on STEM: science, technology, engineering and mathematics. It is the most universal preoccupation currently shaping education and economic plans. A skilled workforce in STEM is considered by many countries to be a high priority for guaranteeing future economic prosperity in a competitive global economy.

The need to expand the STEM workforce has become increasingly pressing in the last 20 years. International research indicates that 75% of the fastest growing occupations now require STEM skills and knowledge. Improving the STEM workforce is a top priority for educators, policy makers, and researchers with the need to: (a) recruit and retain more students to work in STEM-related fields, (b) compete with the global competition, and most importantly (c) improve STEM literacy for all students (Heilbronner, 2011; Office of the Chief Scientist, 2014).

STEM education aims at preparing this kind of workforce by integrating the disciplines of science, technology, engineering, and mathematics in real, authentic, and relevant ways. Therefore, teaching the integrated STEM has gained importance in grades K-12 all over the world. It is perceived that any student who participates in STEM education, particularly in the K-12 setting, would have an advantage if they chose not to pursue a post-secondary education or would have an even greater advantage if they did attend college, particularly in a STEM field (White, 2014). The study of STEM offers students a chance to make sense of the integrated world they live in rather than learning fragmented bits and pieces of knowledge. It removes the traditional barriers erected among the four disciplines, by integrating them into one cohesive teaching and learning paradigm (Lantz Jr, 2009).

STEM as an educational term was first “coined” by the U.S. National Science Foundation (NSF) in the early 2000s. This educational initiative was to provide all students with critical thinking skills that would make them creative problem solvers and ultimately more marketable in the workforce (Dugger, 2010).

Over the past several years, there has been a significant current movement around promoting STEM education. At the request of Congress, four inventories of federal STEM education programs and activities have been published in recent years; two by the Government Accountability Office (GAO), one by the Academic Competitiveness Council (ACC), and one by the National Science and Technology Council (NSTC). The first GAO study, in 2005, found 207 distinct federal STEM education programs funded at about $2.8 billion. In 2007, the ACC found 105 STEM education programs funded at about $3.1billion. A 2011 report by the NSTC identified 252 “distinct investments” in STEM education funded at about $3.4 billion. A second GAO study, published in 2012, reported 209 programs funded at about $3.1 billion (Gonzalez, & Kuenzi, 2012).

As a result of the previous efforts, the number of the STEM schools has increased in the United States. In a survey of STEM schools conducted by Means, Confrey, House, and Bhanot (2008), there were approximately 315 public STEM secondary schools in the US in 2007. Tofel-Grehl and Callahan (2014) reported 358 STEM schools after an extensive search. In 2010, President Obama’s Council of Advisors on Science and Technology called for 1,000 new STEM-focused schools in the next decade (Eisenhart et al., 2015).

Although the number of schools and students earning STEM degrees has grown substantially in the last decade, the supply for the STEM workforce continues to trail the demand. For example, the Bureau of Labor Statistics reported that the U.S. economy is expected to add at least 1.2 million computer science jobs from 2010 to 2020, but at the current pace, U.S.

universities will only produce half the number of computer science graduates needed to fill those positions (Bottia, Stearns, Mickelson, Moller, & Valentino, 2015). By 2018, projections estimate the need for 8.65 million workers in STEM-related jobs (Hom, 2014). Adding urgency to this concern is the fact that some STEM fields have suffered from declining student interest. For example, bachelor's degrees in the physical sciences have proportionately declined in the past several decades (Xie & Achen, 2009).

The previous problem is not unique to the United States. In the United Kingdom, the Royal Academy of Engineering reports that the Brits will have to graduate 100,000 STEM majors every year until 2020 just to meet demand. According to the report, Germany has a shortage of 210,000 workers in the natural science, mathematics, computer science, and technology disciplines (Hom, 2014).

In Egypt, the government recognizes the value of a knowledge economy based on quality education and innovation. For several years now, the Ministry of Education (MOE) has paid increasing attention to science and mathematics, albeit on a small-scale, by supporting traditional and nontraditional institutions and activities. As one of the MOE's key partners in education, the U.S. Government, through USAID, has provided support in this arena when asked. As a result of all these efforts, there are now several institutions and initiatives in Egypt teaching students science and math in innovative ways (USAID/ Egypt, 2012).

Discussions between the MOE and USAID developed into the plan to establish STEM schools, based on the American model. These schools were initiated to meet the needs of the gifted students and to meet the demands of the future workforce and continue research that is central to the economic growth of the country. The goal of the MOE is to establish twenty-seven STEM schools over the course of five years. This would mean one STEM school in each governorate (Rissmann-Joyce & El

Nagdi, 2013).

The first STEM school was established in the 6th of October city in September, 2011. It is a boarding school for talented students that is equipped with computer devices, has 12 laboratories for science, mathematics and engineering. Another school was established for female students in 2012 in Zahraa El-Maadi in collaboration with the Ministry of Education and Misr El-Kheir Foundation. Both schools are accepting gifted students from all over Egyptian governorates (Khadri, 2014).

Despite the success of STEM program in these two schools, there is little to no thoughtfully planned and implemented STEM curriculum. In Egypt, there are 20913 schools in the elementary stage, 13089 schools in the middle stage, and 2874 schools in the secondary stage which continue to teach subjects in isolation, with little to no attempts to draw connections among the STEM disciplines (MOE, 2014). This means that Egypt fails to develop a strategy to improve quality science and math instruction at the elementary, middle, and high school levels, then students may neither have the interest nor the preparation to attend leading Egypt STEM universities.

Several researchers (e. g. Ahmed, 2012; Khadri, 2014; Mohamed, 2014) claim that there is a crisis in Egyptian STEM education today. The current education system does not substantially help students acquire the essential skills in any of the science and mathematics disciplines. Teachers are ill prepared to teach the STEM disciplines of science and mathematics, as revealed by the low numbers of highly qualified teachers. Until now, there are no national STEM standards or STEM teacher certification.

International institutions paint a similarly grim picture of the STEM education in Egypt. In the 2014-2015 edition of the World Economic Forum’s Global Competitiveness report, Egypt ranked 136 out of 144 countries worldwide for the overall quality of its higher education in science and math, 135 for the quality of scientific research institutions, and 141 for the quality of education system (Schwab, 2014).

The Trends in Science and Mathematics Study (TIMSS) identified serious flaws in science and mathematics education in Egypt. In 2003, the Egyptian 8th graders scored 421 in science on average, below the international average of 473, which placed Egypt in the 35th slot out of 45 nations (Gonzales et al., 2004). Four years later, the average science score dropped to 408, below the 2007 TIMSS scale average of 500. This placed Egypt in the 39th slot out of 47 nations (Gonzales et al., 2008).

A key piece of evidence used to support the impending shortages around is that STEM in Egypt is patterns of declining participation rates of students in science and mathematics subjects. The proportion of students enrolling in the science section of the secondary school is declining over time. The percentage decreased from 69.2% in 1970 to 28.2% in 2012. The shrinking number of science and math students and related negative consequences for the country’s economic future is disturbing (MOE, 2014; Rissmann-Joyce & El Nagdi, 2013).

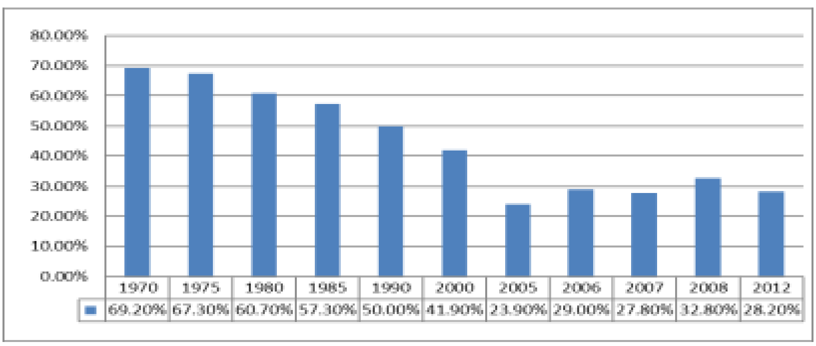


Figure 1. The proportion of students enrolling in the science section of the secondary school from 1970 to 2012

Based on the previous reports, STEM education has come to embody the necessity to improve education and to prepare more students for careers in these burgeoning fields. One of the suggested reform efforts is using the hands-on activities. When students “do science” they gain knowledge and skills that are transferable to future problems and that help prepare them to approach college and career with the tools to succeed. Hands-on activities have an unrivalled potential to help students develop their creativity and critical thinking. Moreover, this kind of activities provides students with an opportunity to practice how scientists really do science and to deeply understand key concepts in science (Kazachkov & Kires, 2014; Supasorn, 2012).

Using hands-on activities in summer programs has more advantages than using the traditional classrooms activities. Several researches (e.g. Çimer, 2012; Vekli, 2013) pointed that there are some limitations to practice in science classrooms. First, the time limitation does not facilitate doing hands-on activities. Second, science curricula indirectly favor memorization facts. Third, classrooms do not provide instruction materials for doing these activities. On the other hand, the nature of summer programs as non-formal learning is to provide students with opportunities to explore, experience, and interact with others as they learn science outside the classroom settings.

Previous studies (Colvin, Lyden, & León de la Barra, 2012; VanMeter-Adams, Frankenfeld, Bases, Espina, & Liotta, 2014; Yilmaz, Ren, Custer, & Coleman, 2010) have proved that the implementation of well-designed hands-on projects and activities in a summer STEM program not only increased the students' satisfaction, but also improved their self-confidence and their interest in STEM. This kind of activities shows hope in enabling a better connection between STEM professions and students.

The current study presents a summer STEM program based on the implementation of hands-on activities to develop design thinking and conceptual understanding. The summer STEM program is an enrichment program for middle school students who desire to strengthen and expand their scientific knowledge and have fun. A variety of STEM concepts are introduced through the hands-on experiments.

This type of STEM program may help in developing design thinking process which is now seen as an exciting new paradigm for dealing with problems in sectors as far afield as education, engineering, technology, IT, business, and medicine (Dorst, 2011). Several studies (e.g. Brophy, Klein, Portsmore, & Rogers, 2008; Sheppard, Pellegrino, & Olds, 2008) call for more research on the instruction of design thinking for the K-12 grade to accurately determine what elements of instruction are most beneficial to student's learning of science and math.

Despite the strong emphasis on the importance of design thinking for students to be successful in a global workforce, there are many factors which can halt design thinking in science education. The accountability to succeed on high-stakes standardized tests in K-12 environments prevents the implementation of design thinking in the curriculum. Educators feel that focusing on classic curriculum will better prepare their students to perform well on these tests. Other issues that may prevent the implementation of design thinking in scholastic settings may be a lack of awareness of the field, educators' uncertainty in implementing new approaches to teaching, and lack of institutional support (Carroll et al., 2010).

The current program may also contribute to developing conceptual understanding which is vital for lifelong learning. Understanding scientific concepts has been one of the primary goals for science studies, at all levels of education. Concepts and conceptual understanding are described as "the most productive means of accessing and framing knowledge in the curriculum" (Chaimala, 2009).

Teaching for understanding is an enormous challenge for science teachers. Among the challenges science teachers face in teaching for understanding is that they have to address students' misconceptions as well as motivate students' interest in learning science. One possible reason for the lack of conceptual understanding among students is that science teachers are relying on teaching methods or strategies that are ineffective in promoting understanding of science (Mansor, Halim, & Osman, 2010). Bulunuz (2012b) found that academic activities just based on science textbooks are not enough for students to understand the basic concepts, and there is a need to include a variety of hands-on science activities.

As a pilot study, the researcher conducted an initial questionnaire on 23 science teachers working in middle schools in Egypt. The questionnaire consisted of three questions: 1) what do you know about STEM?, 2) how can you develop your students' design thinking?, & 3) how can you develop your students' conceptual understanding? The initial questionnaire revealed that 95.65% of the teachers have no information about what STEM is; 100% of them do not know how to develop their students' design thinking; and 78.26% of them have a little information about conceptual understanding and how to develop it. These results indicate that there is a real problem in STEM education in Egypt and low attention towards developing important learning outcomes such as design thinking and conceptual understanding.

A review of existing K-12 STEM education efforts in Egypt points out the lack of empirical studies in authentic environments. This situation explicitly recommends more research on supporting STEM learning in Precollege settings. Yet, there have been very few researches on STEM education in Egypt. A review of literature revealed that no studies have used a hands-on summer STEM program to develop design thinking and conceptual understanding.

Statement of the Problem

The problem of this study is specified in "the weakness in the implementation of the integrated-STEM disciplines in precollege education. This situation causes a shortage in the students design thinking and conceptual understanding". Accordingly, the researcher attempted to answer the following main question:

What is the effectiveness of a hands-on summer STEM program in developing middle school students' design thinking and conceptual understanding?

In attempting to answer this question, the following sub-questions were also answered:

What are the bases of a hands-on summer STEM program for middle school students?

What is the suggested form of the hands-on summer STEM program for middle school students?

What is the effectiveness of the hands-on summer STEM program in developing design thinking?

What is the effectiveness of the hands-on summer STEM program in developing conceptual understanding?

Objectives of the study

The objectives of the present study are:

Developing the students' design thinking by using the hands-on summer STEM program

Developing the students' conceptual understanding by using the hands-on summer STEM program

Definition of Terms

Hands-on activities: all types of collaborative practical work done by students which allow them to handle, observe or operate a scientific process in order to develop design thinking and conceptual understanding.

STEM Program: is an informal program based on the idea of educating students in four specific disciplines- science, technology, engineering and mathematics- in an interdisciplinary and applied approach rather than teach the four disciplines as separate and discrete subjects.

Design thinking: a cognitive process that is used to create exciting feasible wholes from messy infeasible parts. This process enables the students to develop innovative solutions for real world problems. It includes five stages which are: empathize, define, ideate, prototype, and test.

Conceptual understanding: is the ability to integrate the new domain knowledge, relate between ideas, and use the ideas to explain and predict natural phenomena. Progression in understanding can be seen in the ‘‘Structure of the Observed Learning Outcome’’ (SOLO) taxonomy.

Limitations of the Study

The present study is limited to:

A group of middle school students from the Cairo governorate who completed 8th grade and volunteered to attend the summer program.

The schematic d. school design thinking process which consists of the five stages: 1) empathize, 2) define, 3) ideate, 4) prototype, & 5) test.

Four levels of the SOLO taxonomy, which are: 1) unistructural, 2) multistructural, 3) relational, & 4) extended abstract. The first level "prestructural" was neglected because it reflects no understanding.

Research Hypotheses

To solve the study problem, the researcher tested the following hypotheses:

There is a statistically significant difference between the mean scores of the experimental group in the pre-application of the design thinking test versus the post-application, in favor of the post-application.

There is a statistically significant difference between the mean scores of the experimental group in the pre-application of the conceptual understanding test versus the post-application, in favor of the post-application.

Significance of the Study

This study might be of importance to:

Science teachers: this research will be very beneficial to teachers by guiding them to use the hands-on activities in teaching science. It can grab their attention to the importance of the integrated-STEM disciplines and encourage them to develop their students' design thinking. This research may also provide teachers with the ability to enhance and evaluate their students' conceptual understanding.

Curriculum and program designers: this research can grab the attention of curriculum and program designers to place emphasis on the hands-on STEM program.

Students: the direct recipients of the output of this research are the students. Using the hands-on activities in teaching STEM disciplines may help students to enhance their design thinking and conceptual understanding.

Theoretical background

1- STEM education

The term “STEM education” refers to teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels- from pre-school to post-doctorate- in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings (Gonzalez, & Kuenzi, 2012). Moon & Rundell (2012) have referred to STEM as an assemblage of practices and processes that transcend disciplinary lines and from which knowledge and learning of a particular kind emerge.

In order to better understand STEM, several researches (e.g. Dugger, 2010; White, 2014) differentiated among science, technology, engineering, and mathematics. Table 1 summarizes these differences:

Table 1

Differences among science, technology, engineering and mathematics

	S-Science	T-Technology	E-Engineering	M-Mathematics
Definition	The systematic study of the nature and behavior of materials	The branch of knowledge that uses all engineered tools/ devices/ processes to solve practical problems	The art that applies scientific and mathematical knowledge to build/design/ create something	The science of patterns and relationships; it is concerned with the study of number, quantity, shape, and space and their interrelationships
Its processes	Inquiry, discovering, exploring, and scientific method	Managing, understanding, and assessing	Designing, inventing, and solving practical problems	Analyzing, reasoning, and communicating
Its products	Laws that describe phenomena	Meeting human needs	Tools, devices, and processes	Solving mathematical problems

There are a number of ways in which STEM can be taught in grades K-12 in schools today. One way is to teach each of the four disciplines individually in schools. Some refer to this as S-T-E-M. Another way is to teach each of the four disciplines with more emphasis going to one or two of the four. A third way is to integrate one of the STEM disciplines into the other three being taught. For example, engineering content can be integrated into science, technology, and mathematics courses. This may be referred to as: E S T M. A more comprehensive way is to infuse all four disciplines into each other and teach them as an integrated subject matter. For example, there is technological, engineering, and mathematical content in science, so the science teacher would integrate the T, E, and M into the S (Dugger, 2010).

STEM education is very important for all precollege stages. Hom (2014) suggested that Grades K-12 students can study STEM as follows:

Elementary school- STEM education focuses on the introductory level STEM courses, as well as awareness of the STEM fields and occupations. This initial step provides standards-based, structured inquiry-based and real world problem-based learning, connecting the four STEM subjects.

Middle school- the courses become more rigorous and challenging. Student awareness of STEM fields and occupations is still pursued, as well as the academic requirements of such fields. Student exploration of STEM related careers begins at this level, particularly for underrepresented populations.

High school- the program of study focuses on the application of the subjects in a challenging and rigorous manner. Courses and pathways are now available in STEM fields and occupations, as well as preparation for post-secondary education and employment. More emphasis is placed on bridging in-school and out-of-school STEM opportunities.

A true STEM education should increase students' understanding of how things work and improve their use of technologies. STEM education should also introduce more engineering during precollege education (Bybee, 2010). There have been attempts to define the desired results (function) of STEM education. Morrison (2006) outlined several functions of a STEM education. She suggested that students should be:

Problem-solvers- able to define questions and problems, design investigations to gather data, collect and organize data, draw conclusions, and then apply understanding to new and novel situations.

Innovators- creatively use science, mathematics, and technology concepts and principles by applying them to the engineering design process.

Inventors- recognize the needs of the world and creatively design, test, redesign, and then implement solutions (engineering process).

Self-reliant- able to use initiative and self-motivation to set agendas, develop and gain self-confidence, and work within specified time frames.

Logical thinkers- able to apply rational and logical thought processes of science, mathematics, and engineering design to innovation and invention.

Technologically literate- understand and explain the nature of technology, develop the skills needed, and apply technology appropriately.

The effective STEM instruction provides students with opportunities for hands-on experiences and real-world applications of scientific problems. One way to achieve this goal is by offering various extracurricular activities for interested students. Such activities may include summer programs, after school enrichment activities, science fairs or Olympiads, and other competitions (Toulmin & Groome, 2007).

Summer is a great time to explore STEM activities. Students will have the opportunity to broaden their horizons without disrupting academic schedules. They will discover the true meaning of "learning outside the classroom"- observe and experience many of the things they study. The current study presents a summer STEM program which provides hands-on experiences that offer cooperative, investigative and challenging learning-where students get all of the attention as well as the opportunities and encouragement to achieve their best.

Several studies (Dillivan & Dillivan, 2014; Mohr-Schroeder et al, 2014; Supalo, Hill, & Larrick, 2014; Vekli, 2013) have evaluated the effectiveness of various summer STEM programs for different educational stages. The results indicated that the programs increased the students' confidence and interest in STEM fields and motivated them to choose careers in STEM areas. Overall, the participants' STEM knowledge was developed. The data also revealed that the majority of the participants found the STEM programs "fun" and engaging, specifically citing the hands-on experiences they received.

The previous studies give more attention to evaluate existing summer STEM programs. In the scope of the researcher's knowledge, there is no study that aimed at preparing a hands-on summer STEM program and measuring its effectiveness in developing middle school students' design thinking and conceptual understanding.

2- Hands-on activities

Most schools use textbooks to teach science, but hands-on science curricula have become increasingly popular over the last two decades. Hands-on activities enhance learning significantly at all levels of science education. They have an unrivaled potential to help students develop their creativity and critical thinking, provided they are practiced in a minds-on, inquiry-based fashion. Another advantage of the hands-on approach is the extra motivation and professional progress of the teachers (Kazachkov & Kireš, 2014).

The inclusion of hands-on activities in science education has been advocated highly in the last years. It is obvious that there is a shift in emphasis from text book recitation to physical interaction with materials, having the spirit of active learning (Hussain & Akhtar, 2013). Many researches proved that hands-on activities are more effective than academic activities. Bulunuz (2012b) found that academic activities just based on science textbooks were not enough for students to understand the basic physics concepts, and there is a need to include a variety of hands-on science activities. Foley and McPhee (2008) found that students in the hands-on classes were generally more interested in science and had a better understanding of the nature of science than students in textbook classes.

The benefits of hands-on science activities can be summarized in:

Improving students' achievement. Hands-on science fosters the mind in more basic ways by extending the links between the brain and the hand. Researches on the effectiveness of hands-on activities in students' learning indicated improvement in students' achievement (Hussain & Akhtar, 2013; Trnova & Krejci, 2014).

Improving scientific process skills. Hands-on activities emphasize the explicit use of the whole process of science inquiry, in which students have a chance to define the investigated problem from their observations, generate hypotheses, devise a plan and conduct the investigation (Supasorn, 2012). A number of papers have linked hands-on activities to the improvement in students' scientific process skills (Cigrik & Ozkan, 2012; Hirca, 2012).

Developing thinking skills. By investigating the subject matter through hands-on activities, students learn both content and thinking strategies. Hands-on activities support problem-based approaches to learning by focusing on the experience and the process of investigating, proposing and creating solutions. kazachkov and Kireš (2014) found that students' creativity and critical thinking are improved after having been involved in hands-on science activities

Making learning and teaching fun. Hands-on teaching is fun not just for students, but for educators who are eager to go beyond merely presenting information and administering tests. Many studies report that hands-on science activities resulted in greater interest in science and motivation to do science (Wen-jin, Chia-ju, & Shi-an, 2012; Bulunuz, 2012a).

Restoring focus and sparking engagement. With the appropriate planning and presentation, hands-on teaching can restore focus and spark engagement. An independent observation of teachers using hands-on learning noted that students were enthusiastic and generally stayed on-task during guided hands-on activities (Bass, Yumol, & Hazer, 2011).

As a result of the importance of hands-on science activities, 11 international conferences on hands-on science were held between 2004 and 2014. The 1st International Conference on Hands-on Science; "Teaching and Learning Science in the XXI Century" held in 2004, was an excellent forum where 120 participants from 13 EU countries presented 52 works and discussed the main aspects of modern science education establishing the basis for generalization of hands-on experimental work in science education (Costa, 2008). The 11th International Conference on Hands-on Science; “Science Communication with and for Society” was held in 2014. The aim of the conference was to promote science education and its development through an enlarged use of hands-on experiments in the classroom (Pombo, Fábrica, & Dorrío, 2014).

Many programs and projects have been performed to improve the quality of hands-on activities in science education. For example, The Science Education Partnership (SEP) was formed for the purpose of expanding and supporting a quality “hands-on” science program for students from kindergarten to grade 8 (Hutchison, 2014). Moreover, complete curricula of hands-on activities have been developed to effectively replace the use of science textbooks in elementary classroom: Full Option Science System (FOSS; Delta Education), developed at the Lawrence Hall for Science at the University of California; Science and Technology for Children (STC; Carolina Biological Supply Company), developed by the National Science Resources Center; and The Insights curriculum which was created to immerse teachers and students in the true process of inquiry (Foley & McPhee, 2008).

Different instructional methods were adopted in these programs and curricula in order to implement hands-on science techniques. Several authors (e.g. Miller, 2014; Ruby, 2001) described the most frequently utilized teaching approaches for hands-on science which include:

The verification approach. It is effective in making an abstract model more concrete. However, verification learning technique is criticized on two fronts: its overuse can result in wasting time on repetitive activities, and its procedure only allows learners to merely follow directions and observe the outcomes without using their own capacities to comprehend what should transpire, how it is done, and what it means.

The discovery approach. It involves providing students with needed materials to work, but offers little guidance on what to do or what investigation is expected. The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge.

The exploratory approach. It may seem similar to the discovery approach, but is actually more closely connected to the verification approach. With the explanatory method, students are given the required materials, and then issued instructions on the expectations, with little direct guidance. The purpose is to make students confident and comfortable with the topic under study, arouse their interest, and inspire them to raise questions.

The process skills approach. It attempts to instill specific processes used in science without consideration for any particular science discipline or topic. However, the process skills approach has been criticized based on reasoning that science content is inseparable from the process since content is vital to problem solving. Teachers use process skills including the skills of prediction, observation, inference, and measurement. These skills could build a bridge connecting what is familiar and accessible to what is unfamiliar and abstract within the science curriculum.

In sum, the hands-on activities provide students with opportunities to engage in exploration and sense making with the science content. Engaging students in hands-on activities in the summer STEM program may provide a powerful learning experience where students not only learn about STEM content but also gain reasoning and research skills. Students may understand the nature of problem solving as the pursuit of meaningful questions through the use of procedures that are thoughtfully generated and evaluated.

3- Design thinking

Design thinking is one of the most recent terms that have been suggested for use in schools in a variety of curricular ways. Design thinking is currently being taught in "workshops, supplemental training, courses, or degree programs" in over 60 universities and colleges (Goldman, Kabayadondo, Royalty, Carroll, & Roth, 2014). Many design schools in North America and elsewhere now include course offerings in design thinking. Design thinking is increasingly used to refer to the human-centered ‘open’ problem solving process. Claims have been made that design thinking in this sense can radically improve not only product innovation but also decision making in many fields (Melles, Howard, & Thompson-Whiteside, 2012).

Design thinking is "a complex cognitive process" of creating exciting feasible wholes from messy infeasible parts. It is about selecting a desired future and inventing the ways to bring it about. Design thinking develops innate abilities in dealing with real-world, ill-defined, ill-structured, or “wicked” problems (Gharajedaghi, 2011). Razzouk and Shute (2012) defined design thinking as an analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign.

Holloway (2009) describes and exemplifies the design thinking practices "…design thinking looks beyond the immediate boundaries of the problem to ensure the right question is being addressed. Using interdisciplinary teams, design thinking incorporates diversity and leverages different paradigms and tool sets from each profession to analyze, synthesize, and generate insights and new ideas. The interdisciplinary nature of design thinking also ensures that innovations are naturally balanced between the technical, business, and human dimensions".

While there may never be agreement on a single definition of design thinking, the need for design thinkers is widely recognized (Charnley, Lemon, & Evans 2011). Increasing exposure to design thinking in precollege classroom settings can facilitate learning of STEM disciplines and increase interest in STEM careers. In the K-12 arena, design thinking is employed to promote creative thinking, teamwork, and student responsibility for learning (Chiu, 2013). In addition to enriching the curriculum and expanding student perspectives, design thinking can also benefit educators. Researchers have proposed that design thinking can enable educators to integrate technology into the classroom (Tsai & Chai, 2012).

A lot of work has been published in recent years on design thinking and how designers think (Cross, 2011; Lawson & Dorst, 2009). A frequently held consensus across those publications is the notion that design thinking has a number of common features, typified and manifest in a strong commitment and personal motivation of the individual. Moreover, it is widely suggested that designers possess courage to take risks, they are prepared to fail, and they work hard. Furthermore, during their design thinking activities, designers regularly (re) define and/or frame the problem; adopt holistic thinking; and sketch, draw, and model possible ideas throughout the design process (Goldschmidt, & Rodgers, 2013).

Blizzard et al. (2015) developed questions intended to identify design thinking traits. They tested these questions in a national survey distributed to U.S. college students. By applying exploratory factor analyses and regression models to the survey data, nine of the questions were mapped to five related characteristics of design thinking: collaboration, experimentalism, optimism, feedback-seeking, and integrative thinking. Survey questions alone cannot fully identify the qualitative traits of design thinkers, but these nine questions do enable basic exploration of compelling relationships between design thinking traits and other variables.

Several different models of the design thinking process have been proposed, including a three-step simplified triangular process (Inspiration, Ideation, & Implementation) by Brown (2008), and the six sequential stages from the d.school (design school) which consisted of the six stages, Understand, Observe, Point Of View, Ideate, Prototype, and Test, but an actual process can be much more elaborate due to the many feedback loops that are involved (Carroll et al., 2010). The d.school also published a model consisting of five stages in their d.school Bootcamp Bootleg paper. These stages are (Plattner, 2010):

Empathize: work to fully understand the experience of the user for whom the students are designing. The students do this through observation, interaction, and immersing themselves in their experiences.

Define: process and synthesize the findings from their empathy work in order to form a user point of view that they will address with their design.

Ideate: the students explore a wide variety of possible solutions through generating a large quantity of diverse possible solutions, allowing them to step beyond the obvious and explore a range of ideas.

Prototype: the students transform their ideas into a physical form so that they can experience and interact with these ideas and, in the process, learn and develop more empathy.

Test: the students try out high-resolution products and use observations and feedback to refine prototypes, learn more about the user, and refine their original point of view.

Figure 2. The d.school design thinking process (Ryshke, 2015)

There are currently many researchers exploring the intersection of design thinking and education. A number of researchers (e.g. Kangas, Seitamaa- Hakkarainen, & Hakkarainen, 2013; Mentzer, 2013) explored the multimodal ways of design thinking among teams of students, particularly K-12 students, while they engaged in a collaborative engineering design challenge. Other researchers tried to improve understanding of the role of design thinking in K-12 classrooms. Donar (2011) surveyed different approaches adopted in five post-secondary design thinking programs in the hope of drawing a matrix in order to analyze their strengths and weaknesses and examine what they have in common. Carroll et al. (2010) focused on the implementation of an interdisciplinary design curriculum by a team of university instructors in a public charter school.

Developing the students' design thinking caught the attention of other studies. Lloyd (2013) used distance education to teach design thinking. Anderson (2012) outlined a project to develop and track design thinking skills within groups of students in late primary and early secondary years of schooling in order to strengthen their creative skills and innovative mindsets.

In sum, the formal and informal education in Egypt are in dire need of introducing design thinking to K-12 students in order to promote learning science and increase interest in STEM careers. However, a review of existing K-12 science education efforts in Egypt points out the lack of empirical studies on design thinking in authentic classrooms, therefore, more research on supporting design thinking in precollege settings should be conducted.

4- Conceptual understanding

Conceptual understanding is described as knowledge that is rich in relationships so that all pieces of information link to some network. Konicek-Moran and Keeley (2015) stated that conceptual understanding is very much like making a cake from scratch without a recipe versus making a cake from a packaged mix. With the packaged mix, one bakes the cake by following the directions on the box without really understanding what goes into making a cake. However, in making the cake from scratch, one must understand the types of ingredients that go into a cake and cause-and-effect relationships among them. In other words, making the cake from scratch involves conceptual understanding rather than simply following a recipe.

Conceptual understanding is what learners know and understand about a concept, that is; the generalizations learners can develop about the nature or properties of that concept (Ministry of Education, 2009). It permits one to transfer an explanation of a phenomenon to different variants of a situation that have been previously analyzed (Viennot, 2009). Claesgens, Scalise, Wilson, & Stacy (2009) described conceptual understanding as understanding beyond rote memorization of facts. The shift is from student answers limited to scientific terms to student explanations of their understanding in terms of their ability to integrate the new domain knowledge, relate between ideas, and use the ideas to explain and predict natural phenomena.

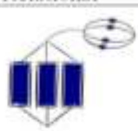
The development of conceptual understanding is cumulative. As learners return to familiar concepts in different contexts throughout their learning, they gradually increase the breadth, depth, and subtlety of their understanding. Progression in conceptual understanding can be seen in the SOLO taxonomy. SOLO is short for “Structure of the Observed Learning Outcome” and the taxonomy names and distinguishes five different levels according to the cognitive processes required to obtain them: “SOLO describes a hierarchy where each level becomes a foundation on which further learning is built”. The five levels are shown in table 2, in order of increased structural complexity (Biggs and Tang, 2011; Hook, 2015):

As you move up the SOLO hierarchy, you first see quantitative improvements as the student becomes able to deal with first a single aspect (from 1 to 2) and then more aspects (from 2 to 3). Later you see qualitative improvements (from 3 to

4) as the details integrate to form a structure; and (from 4 to 5) as the structure is generalized and the student can deal with information that was not given (Brabrand & Dahl, 2009).

Table 2

The description of the five levels of the SOLO taxonomy

Level	Description
 Prestructural	The student has no understanding of the concept. He shows unconnected information, with no organization.
 Unistructural	The student focuses on one single aspect. He is able to paraphrase, define, identify, count, name, recite, etc. E.g. What are the symptoms of Parkinson's disease (PD)?
 Multistructural	The student focuses on several relevant aspects, but these aspects are treated independently. He is able to combine, enumerate, describe, classify, list, apply methods, structure, execute procedures, etc. E.g. What is happening in the brain of a PD patient?
 Relational	The student understands the relations among several aspects and how they might fit together to form a whole. He is able to compare, integrate, relate, analyze, apply theory, explain causes, etc. E.g. How do the various treatment options attempt to correct PD symptoms?
 Extended abstract	The student is able to create new ideas based on his mastery of the subject and transfer ideas to new areas. He is able to generalize, hypothesize, criticize, theorize, predict, judge, transfer theory, etc. E.g. Why was the frozen addicts' case so important for understanding PD?

Promoting students' conceptual understanding has long been one of the most important goals for science education. Conceptual understanding is described as “the most productive means of accessing and framing knowledge in the curriculum. Without an understanding of science concepts it would be nearly impossible for students to follow much of the public discussion of scientific results or public policy issues pertaining to science and technology (Enger & Yager, 2009).

Because of the importance of conceptual understanding, it has received considerable attention of the research literature in science education. Several researches tried to identify the students' conceptual understanding (e.g. Bayrak, 2013; Kim, VanTassel-Baska, Bracken, Feng & Stambaugh, 2014). Other studies developed students' conceptual understanding by using different strategies and methods such as: problem-based learning (Yurick, 2011), peer instruction (Gok, 2012), reflective peer assessment (Lin, Hong, Wang, & Lee, 2011), Argumentation Based Science Teaching (Çınar & Bayraktar, 2014), the 5E constructivist model (Artun & Coştu, 2013), and argument-driven inquiry (Walker, Sampson, Grooms, Anderson, & Zimmerman, 2012).

In these studies, it is observed that the notion of conceptual understanding is used in different and sometimes incompatible ways, guided or determined by theoretical beliefs about knowledge and learning. This is mainly due to the fact that ‘understanding’ is closely linked to ‘learning’, and that any account to learning considers inevitably the nature of the knowledge to be taught. Therefore, a theoretical examination of the notion of conceptual understanding should be seen in relation to theories about knowledge and learning (Chaimala, 2009).

According to behaviorism, scientific knowledge is viewed as a specific entity, existing outside the human mind; the aim of science is to discover the true nature of reality, while learning science is about knowing the truth. Learning in a behaviorist perspective is context-independent and it takes place as a result of an external set of stimuli and reinforcements. Under such a learning paradigm, students should exhibit behavioral skills (like knowing to handle equipment) and low-level cognitive skills (such as the ability to repeat definitions). Therefore, in the behaviorist perspective, understanding of scientific concepts could be seen as synonymous to acquiring information about scientific concepts and being able to repeat it. A common criticism of behaviorism is that it often results in rote learning and recall of information with limited understanding (Chaimala, 2009).

In terms of constructivism foundations, knowledge in the framework is conceived as a creation of the mind, an active process of sense making. Sense making can include interacting with the world around us as well as engaging in constructive and instructional activities. Prior knowledge and beliefs are building blocks for sense making. Students can construct and build conceptual understanding as they encounter and grasp increasing levels of complexity in concepts over time (Claesgens et al., 2009).

According to social constructivism, knowledge is neither given nor absolute, but is rather an individual construct in the social contexts in which actions occur. In science education, this theory builds mainly on the work of Vygotsky, and views learning as a social activity in which learners make meaning through both individual and social activities, like discussions and negotiations with teachers and other learners (Chaimala, 2009).

In light of constructivism and social constructivism theories, to develop new conceptual understanding, students need to build connections with other concepts that they already know. Andersson and Wallin (2006) recapitulate what they consider as appropriate to promote learning with understanding:

The teacher looks upon himself as an active representative of the scientific culture, who introduces concepts, gives scientific explanations, and arranges situations for applications of these concepts and so on.

The teacher is well acquainted with common alternative ideas of the teaching content and is aware of these during teaching.

The teacher creates a permissive classroom climate in which the students can share and discuss their ideas and reflections in a positive way.

A fair amount of time is used for discussing and solving problems that involves the students in having to apply the teaching content in different situations.

Deep learning is encouraged; that is, the student is stimulated to connect new knowledge with existing knowledge.

The teacher does not assume that the student is motivated, but acts to create interest and motivation.

Formative evaluation is used in various ways by both teachers and students with the purpose of improving teaching and learning.

Jonassen (2006) suggested that; firstly, conceptual learning must be assessed by examining the understanding students have about patterns of concepts and about how those concepts relate (or do not relate) to one another, rather than examining the students' understanding of concepts in isolation. Secondly, a student's knowledge of concepts can best be examined when the student is using those concepts in a variety of different contexts.

In sum, students' understanding in Egyptian classrooms is vital for their future and lifelong learning. Teaching for understanding is an enormous challenge for science teachers. The current study tries to introduce a model that can be useful to overcome this challenge. The use of hands-on activities may provide teachers with a productive means to achieve deep understanding.

Methodology

1. Research Design

The study employed a one-group pre/post-test quasi-experimental research design in collecting data from students. This design was selected because the experiences in the summer STEM program are totally new for the students and it would allow the researcher to compare the performance of the experimental group before and after the program.

2. Participants

The participants of the program were 28 middle school students who completed 8th grade and volunteered to attend the summer program. Their ages ranged from 14 to 15 years. The students were selected from three different middle schools located in the same district (i.e. El Basateen district, Cairo).

3. Instruments

The basic philosophy of the summer STEM program is to explore the world of science, technology, engineering, and mathematics not by watching but by doing in contrary to what occurs in traditional education classrooms. The program attempts to promote a clear pathway from school to STEM careers by using exciting and fun hands-on science activities. The program tries to help the students to become junior scientists and engineers.

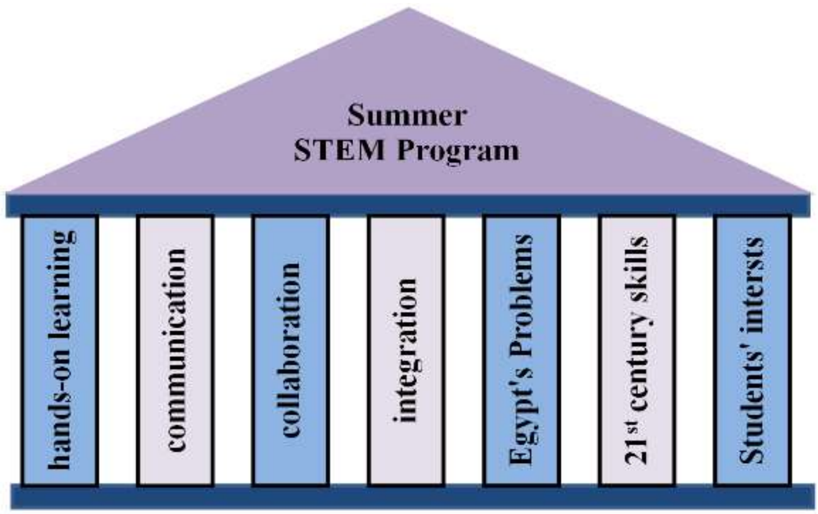


Figure 3. Main-bases of the summer STEM program

In light of this philosophy, the researcher studied the nature of integrated-STEM education, researches on STEM education, researches on hands-on activities, and several summer programs. An initial list of the bases which should be taken into account when designing the summer STEM program was prepared. This initial list contained 36 sub-bases which were grouped into seven main-bases: hands-on learning, communication, collaboration, integration, Egypt's problems, 21st century skills, and students' interests. Five experts in the field of science education were asked to determine if these bases were suitable for designing the summer STEM program. They removed 3 sub-bases; therefore, the final list consisted of 33 sub-bases.

According to these bases, the researcher determined the main topic of the STEM program which is "Means of Transport". To describe the knowledge and skills students are expected to master by the end of this program, the researcher analyzed a number of STEM standards studies (e.g. Carr, Bennett, & Strobel, 2012; Roehrig, Moore, Wang, & Park, 2012). A list including STEM standards was prepared. As shown in table 3, the standards of science include 20 indicators, the standards of technology include 14 indicators, the standards of engineering include 15 indicators, and the standards of mathematics include 15 indicators.

Table 3

STEM standards of the hands-on summer program

Science	Technology	Engineering	Mathematics
The student will:	The student will:	The student will:	The student will:
Describe the motion of an object in nature (6 indicators)	Analyze information relative to the characteristics of technology and apply in a practical situations (5 indicators)	Apply a structured approach to solving real world problems (7 indicators)	Apply a wide variety of mathematical concepts, processes, and skills to solve a broad range of problems in various content areas and everyday situations (7 indicators)
Demonstrate an understanding of the principles of force and motion and relationships between them (10 indicators)	Apply the core concepts of technology in practical settings (6 indicators)	Design products and systems (8 indicators)	Accurately and clearly present and justify mathematical ideas in diverse formats (4 indicators)
Demonstrate an understanding of the conservation, transfer, and transformation of mechanical energy (4 indicators)	Analyze the relationships among technologies and explore the connections between technology and other fields of study (3 indicators)		Use concepts and tools of measurement to describe and quantify the world (4 indicators)

To reach these standards, the student book of the summer STEM program was prepared in light of the bases which have been determined in a previous step. The content and activities were identified from popular and attractive science topics to increase students' motivation. The student book contained one unit which consisted of five lessons covering Transport system, Road transport, Ship transport, Aviation, and Space transport. Concepts of many activities were selected among the topics which students have not studied before in their formal learning environment. Table 4 shows the content of the summer STEM program. The instructor guide was prepared to help in using the hands-on activities in teaching integrated-STEM. The program standards, content, student book, and instructor guide were examined by five experts in science education. They confirmed that the program could be useful after the modifications they suggested were done.

Table 4

The content of the summer STEM program "Means of Transport"

lesson	Main ideas	Hands-on activities	Time
Transport system	The history of transport- The Invention of the Wheel- The role of wheels in reducing friction- Development of means of transport velocity- Velocity concept and its unit of measurement- Components of transport system- Reasons of paying attention to transport means- Transport industry	What does friction cause?- ways to reduce friction- Design of electric car- Measuring the velocity of the electric car	10 hours
Road transport	History of road transport- Bicycle- Friction in the bicycle- Cars, buses, trucks- Rocket car Control system in car- The relation between velocity and acceleration- Road accidents problem- Trains and its types- Hovercraft vehicles	Design of wind car- Design of rubber band car- Design of rocket car- Design of balloon hovercraft	10 hours
Ship transport	Ship transport concept- Development in ship transport- Types of ship transport- Ships and submarines- Resultant force- The Newton's first law of motion	Design of water power boat- Design of paddle boat- Cartesian diver- Design of bottle submarines	8 hours
Aviation	History of aviation- Forces on an Airplane- The Newton's second law of motion- Wight and mass- Types of planes- Jet plane- The Newton's third law of motion- Parachute landing and free fall- Airship	Design of balloon jet- Design of hot air balloon	7 hours
Space transport	History of space transport- Space rocket Space shuttle- potential energy- kinetic energy- conservation of energy law	Design of whoosh rocket- Design of water rocket	5 hours

In order to assess the students' design thinking, the researcher reviewed several studies which aimed at measuring the students' design thinking process (e. g. Kress & Schar, 2012; Meinel, Leifer, & Plattner, 2011). After reviewing the previous studies, the researcher chose "the Windaloobah Experiment" to measure design thinking. The Windaloobah Experiment was created as a performance-based assessment task by Goldman and his team in Stanford University School of Education (Goldman et al., 2012). They created this assessment task to gauge students' design thinking process. The Windaloobah Experiment was structured as an hour long design challenge. The students were asked to work in teams to design a Windaloobah, however, the definition of a Windaloobah (a made up word) was deliberately ambiguous. Students watched a brief introductory video after which they were given information packets with profiles of people who would be part of the community embarking on a journey on the Windaloobah. Table 5 includes the video script.

Table 5

The script of the video which describes the Windaloobah Experiment

Welcome to the Windaloobah Experiment. It is the year 2125. A group of brave and adventurous explorers has joined the Windaloobah experiment. For the next 15 months they have no permanent home. Your job is to design a Windaloobah. What is a Windaloobah? • A Windaloobah must have room for 5 people. • A Windaloobah must travel through water, skies, snow. It must be able to move through cities. It must be ready for unexpected adventures. • A Windaloobah is a home away from home.

In the current study, the students were asked to work in groups to answer a number of questions about the designing of the Windaloobah, for example: Who are you solving for? What are their needs? How will you solve their problem? Why does your work matter?

To evaluate the performance of the students while they try to answer these questions, the researcher prepared an observation card according to the design thinking rubric which was created in October, 2010, by the Henry Ford Learning Institute (HFLI) as a prototype for how to capture the student design thinking growth. The levels within the rubric, ranging from 1 to 4, could be applied to high school and middle school students. This rubric covers the five stages of design thinking which are: Empathy, Define, Ideate, Prototype, and Test (Royalty, 2010).

The rubric included four levels: one score = level 1, two scores = level 2, three scores = level 3, and four scores = level 4. The total score for design thinking process is 20 points (4 scores × five stages). Experts confirmed that the design thinking instrument which included the Windaloobah Experiment and the observation card could be useful after the modifications they suggested were done. A reliability test was applied on 12 students at grade 8 in New Maadi middle school, at the beginning of the second semester, 2014; this group is not part of the participants previously mentioned. Two observers were assigned to observe the students by using the observation card. Cooper's equation was used to calculate the ratio agreement between the observers. It was calculated by dividing the total number of agreements by the total number of agreements plus the total number of disagreements. Average reliability was 86.7%, which suggested that the observation card represented a valid measure of students' design thinking. The instrument took approximately one hour for students to complete.

The conceptual understanding test was prepared according to the SOLO taxonomy levels. These levels are: Unistructural, Multistructural, Relational, and Extended Abstract. The first level "Prestructural" was neglected by the test because it reflects no understanding. In order to prepare this test, the learning outcomes of the program were classified on the basis of the SOLO taxonomy levels to describe the increase of complexity in a student's understanding. Examples are shown in figure 4.

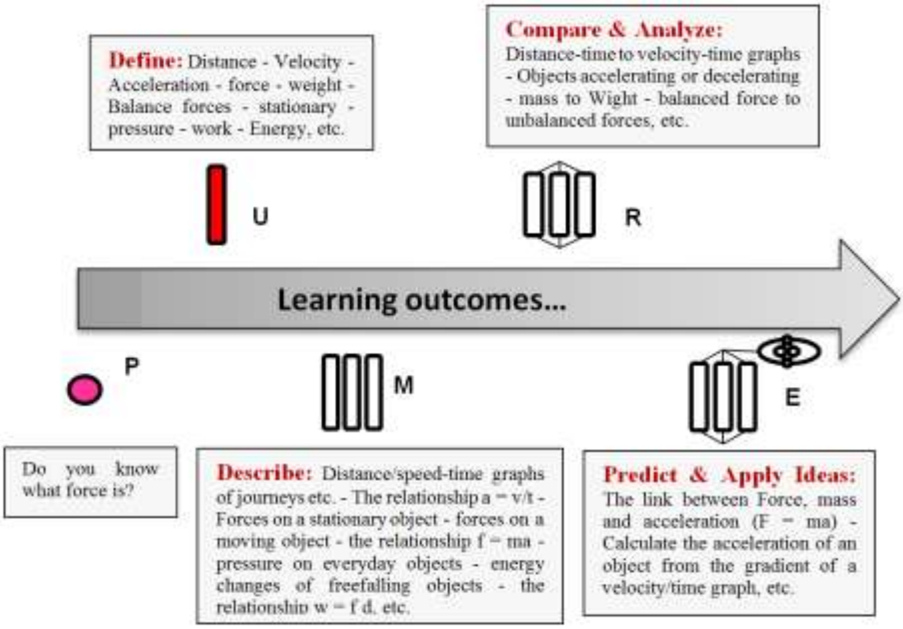


Figure 4. Outcomes of the program on bases of the SOLO taxonomy levels

The conceptual understanding test comprised 32 multiple-choice items. At the beginning of each item there was a question or an incomplete statement followed by four choices which included the answer and three distractors. The test was examined by a number of science education experts in the field, and revised according to their suggestions. The final test consisted of twenty eight items so that the total score was 28 points. For reliability, the final test was piloted over a period of two weeks on a group of grade 8 students in New Maadi middle school, at the beginning of the second semester 2014; this group is not part of the participants previously mentioned. Test-retest Pearson correlation coefficient was 0.76 and the reliability coefficient obtained was 0.863. The test took approximately 38 minutes for students to complete.

Table 6

Classifying of the conceptual understanding items on lessons and the SOLO taxonomy levels

Level / Lesson	Items numbers				Total items	percentage
	Unistructural	Multistructural	Relational	Extended Abstract		
Transport system	1-5	2-6	3-7	4	7	25%
Road transport	9-13	10-14	11	8-12	7	25%
Ship transport	17	18	15	16	4	14.3%
Aviation	21	22	19-23	20-24	6	21.4
Space transport	25	26	27	28	4	14.3%
Total items	7	7	7	7	28	
percentage	25%	25%	25%	25%		100%

4. Procedures

The study was conducted at "The Cultural, Scientific and Religious Services Association" which is one of the non-governmental organizations in El Basateen district, Cairo. The design thinking instrument and the conceptual understanding test were administrated to the group before the intervention. The summer STEM program was then launched on May 15, 2015 and lasted for two weeks (10 days or 40 hours). Through the program, the students were engaged in hands-on activities to improve their design thinking and deepen their understanding of science concepts through the integration of STEM disciplines. Upon completion of instruction, post-tests were conducted to determine the improvement in the students' performance. The data was submitted into SPSS. The t-test was used to determine statistical differences between students’ scores before and after the summer STEM program.

Results

The instrument of the design thinking was applied to determine the effect of the hands-on summer STEM program on the students' design thinking.

Table 7

Design thinking: means, standard deviations and t-value of the pre-test and post-test scores

Stages	Total scores	Pre-test		Post-test		t-value	P
		M	SD	M	SD		
Empathy	4	1.29	0.59	3.29	0.46	19.4	0.00
Define	4	1.21	0.42	3.25	0.51	21.2	0.00
Ideate	4	1.18	0.47	3.21	0.49	18.6	0.00
Prototype	4	1.11	0.31	3.07	0.53	20.4	0.00
Test	4	1.03	0.19	2.96	0.42	21.9	0.00
Total	20	5.82	1.74	15.78	1.97	28.7	0.00

df = 27 $p < 0.01$ significant

The results of the analysis presented in table 7 show that the difference between the design thinking pre-test mean score (5.82; i.e. 29.1%) and post-test mean score (15.78; i.e. 78.9%) is significant (t = 28.7, p <0.01). For the stages, the results show that the mean score of "Empathy" stage after treatment (3.29; i.e. 82.1%) is higher than before treatment (1.29 i.e. 32.1%). These means are significantly different (t=19.4; P<0.01). The mean score of "Define" stage after treatment (3.25; i.e. 81.25%) is higher than before treatment (1.21; i.e. 30.36%). These means are significantly different (t=21.2; P<0.01). The mean score of "Ideate" stage after treatment (3.21; i.e. 80.35%) is higher than before treatment (1.18; i.e. 29.46%). These means are also significantly different (t=18.6; P<0.01). The mean score of "Prototype" stage after treatment (3.07; i.e. 76.8%) is higher than before treatment (1.11; i.e. 27.67%). These means are significantly different (t=20.4; P<0.01). The mean score of "Test" stage after treatment (2.96; i.e. 74.1%) is higher than before treatment (1.03; i.e. 25.9%). These means are significantly different (t=21.9; P<0.01).

Effect size:

In this study, effect size was reported to recognize the magnitude of the treatment effect on students' learning using Cohen's d. The criteria for identifying the magnitude of an effect size is as follows: (a) a trivial effect size is below 0.2 standard deviation units; (b) a small effect size is between 0.2 and 0.5 standard deviation units; (c) a medium effect size is between 0.5 and 0.8 standard deviation units; and (d) a large effect size is 0.8 or more standard deviation units (Sheskin, 2003). The effect size calculation regarding design thinking indicated that the Cohen's d index is large (d= 11.05). These results prove that the hands-on summer STEM program is effective in developing middle school students' design thinking.

The conceptual understanding test was applied to determine the effect of the hands-on summer STEM program on the students' understanding.

Table 8

Conceptual understanding: means, standard deviations and t-value of the pre-test and post-test scores

Levels	Total scores	Pre-test		Post-test		t-value	P
		M	SD	M	SD		
Unistructural	7	2.36	0.91	6.11	0.73	24.8	0.00
Multistructural	7	2.21	0.62	5.92	0.86	29.8	0.00
Relational	7	2.07	0.53	5.75	0.89	31.8	0.00
Extended Abstract	7	1.82	0.72	5.46	1.17	28.4	0.00
Total	28	8.46	2.38	23.25	3.46	34.3	0.00

df = 27 $p < 0.01$ significant

The results of the analysis presented in table 8 show that the difference between pre-test mean score (8.46; i.e. 30.23%) and post-test mean score (23.25; i.e. 83.04%) for the conceptual understanding is significant (t = 34.3, p <0.01). For the levels, the results show that the mean score regarding ‘Unistructural’ level after treatment (6.11; i.e. 87.2%) is higher than the mean score before treatment (2.36 i.e. 33.7%). These means are significantly different (t=24.8; P<0.01). The mean score regarding ‘Multistructural’ level after treatment (5.92; i.e. 84.7%) is higher than the mean score before treatment (2.21; i.e. 31.6%). These means are significantly different (t=29.8; P<0.01). The mean score regarding ‘Relational’ level after treatment (5.75; i.e. 82.14%) is higher than the mean score before treatment (2.07; i.e. 29.6%). These means are significantly different as well (t=31.8; P<0.01). The mean score regarding ‘Extended Abstract’ level after treatment (5.46; i.e. 78.1%) is higher than the mean score before treatment (1.82; i.e. 26.02%). These means are significantly different (t=28.4; P<0.01).

Effect size:

The effect size calculation regarding conceptual understanding indicated that the Cohen's d index is large (d= 13.2). These results prove that the hands-on summer STEM program is effective in developing middle school students' conceptual understanding.

Discussion

The results show that the hands-on summer STEM program had an effect on the students' design thinking. Before treatment, the students' design thinking was very low; (29.1%), while their design thinking became very high; (78.9%), after treatment. For the stages of the design thinking process, figure 5 shows that the performance after treatment outweighs the performance before treatment in all stages of the design thinking process. It also shows that 'Empathy' was the most straightforward stage of the design thinking process, while 'Test' was the most challenging stage.

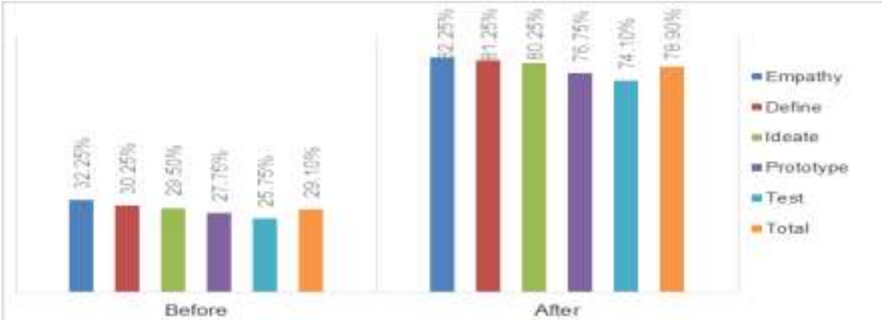


Figure 5. Comparison between design thinking before and after treatment

The differences between the mean scores before and after treatment suggest that hands-on STEM program enhanced the students' performance. Hands-on STEM activities moved beyond theory and dived into practice by engaging the students in creative challenges that have inspired and empowered them to develop real world solutions, tackle realistic innovation challenges from start to finish, and gain an in-depth understanding of the key tenets of design thinking and how to incorporate them into everyday challenges. Through these activities, the students went into each stage of the design thinking process in depth. They empathized with customer needs, synthesized their learning, and rapidly prototyped and tested their new ideas.

Design thinking is a social process that involves working across different perspectives and often involves considerable conflict and negotiation. The hands-on activities increased the students' collaboration skills through working in teams. Gaining these skills helped in improving the students' design thinking. By collaboration skills the students explored how human-centered design can help develop innovative solutions for the complex challenges. These findings are consistent with previous research on the effectiveness of hands-on programs (Colvin et al., 2012; Kazachkov & Kires, 2014; VanMeter-Adams et al., 2014; Yilmaz et al., 2010)

The results also show that the hands-on STEM program had an effect on the students' conceptual understanding. After treatment, the students achieved significant learning outcomes for conceptual understanding as a whole as well as for each level. Figure 6 shows that 'Unistrucral' was the most straightforward level of conceptual understanding, while 'Extended Abstract' was the most challenging level.

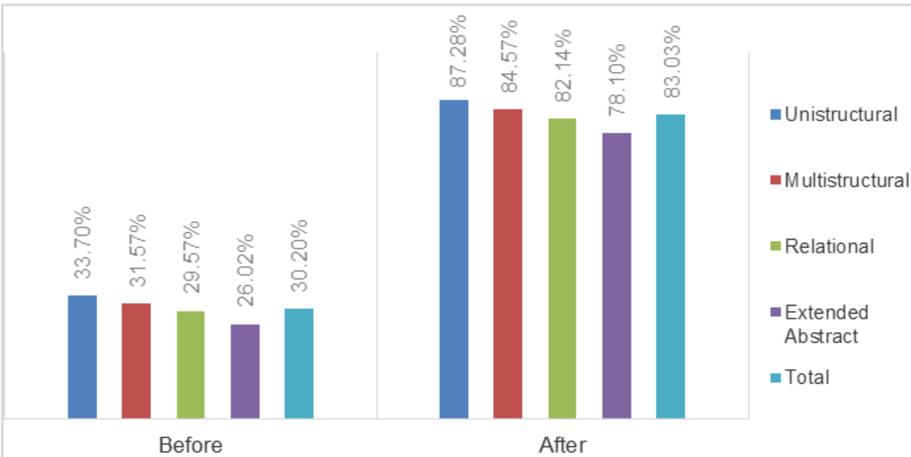


Figure 6. Comparison between conceptual understanding before and after treatment

The differences between the mean scores before and after treatment suggest that the hands-on STEM program enhanced the students' conceptual understanding. Hands-on activities fostered the mind in more basic ways by extending the links between the brain and the hand. Different memories were identified for different functions. Those are auditory, visual, tactile, and body motor functions. This implies that any information which utilizes all four memories would be stronger and easily retrievable.

According to social constructivism, knowledge is an individual construct in the social contexts in which actions occur. Hands-on activities can be considered as social activities in which learners make meaning through both individual and social activities, like discussions and negotiations with teachers and other learners. As a result, learning becomes more meaningful and lasting. This helps students to develop and increase the concepts on their own conceptual understanding.

Hands-on activities helped students to make connections among their experiences. In this way abstract concepts became concrete in their minds and the students interacted with concepts at a deeper level. These findings are in agreement with literature of the effectiveness of hands-on instruction. Banerji, Stoddard, & Dorrío (2014) and Trnova & Krejci (2014) have linked hands-on activities to the improvement in students' understanding.

Conclusion

In this study, the researcher aimed at finding out the effect of a hands-on summer STEM program on students' design thinking and their conceptual understanding. The findings showed that middle school students' design thinking and conceptual understanding increased after the program. The hands-on activities were found to be useful in learning STEM disciplines. Throughout the summer program, students experienced the fun and excitement of STEM in a shared community of peer learners. Activities involved students in collaborative investigations including observation; guided inquiry; socialization; and interaction with experts, peers, and instructors. These findings have wider implications for teaching and assessing deeper approaches to STEM education. The findings indicate that the focus should be on the implementation of informal hands-on experiences that increase interest in STEM disciplines for school students. Science educators, curriculum developers, and textbook writers should work together to support the STEM curriculum in informal and formal education. Examinations for STEM school students should not be traditional exams, but should test the innovation and creativity of students. Exams should be in the form of creating projects to solve one of the society's problems in a new way. The SOLO taxonomy could be a useful tool for developing and assessing deep learning in STEM education. Furthermore, STEM teachers should receive sufficient training in hands-on activities and assessment of students' design thinking and conceptual understanding. Applying these procedures would definitely enhance STEM education in Egypt.

References

Foreign References

1- Anderson, N. (2012). Design thinking: Employing an effective multidisciplinary pedagogical framework to foster creativity and innovation in rural and remote education. Australian and International Journal of Rural Education, 22 (2), 43-52.

2- Andersson, B. & Wallin, A. (2006). Developing Content-oriented Theories. International Journal of Science Education, 26 (9), 673-695.

3- Artun, H., & Coştu, B. (2013). Effect of the 5E model on prospective teachers' conceptual understanding of diffusion and osmosis: A mixed method approach. Journal of Science Education and Technology, 22 (1), 1-10. doi: 10.1007/s10956-012-9371-2

4- Banerji, N., Stoddard, D., & Dorrio, B. (2014). Hands-on Conceptual Teaching of Physics of Music. Paper presented at the 11th International Conference on Hands-on Science, University of Aveiro, Portugal.

5- Bass, K. M., Yumol, D., & Hazer, J. (2011). The Effect of Raft Hands-on Activities on Student Learning, Engagement, and 21st Century Skills. RAFT Student Impact Study. San Francisco: Rockman et al.

6- Bayrak, B. K. (2013). Using two-tier test to identify primary students' conceptual understanding and alternative conceptions in acid base. Online Submission, 3 (2), 19-26. doi: 10.1111/j.1467-8535.2006.00695.x

7- Biggs, J., & Tang, C. (2011). Teaching for quality learning at university: What the student does. Berkshire: McGraw-Hill Education.

8- Blizzard, J., Klotz, L., Potvin, G., Hazari, Z., Cribbs, J., & Godwin, A. (2015). Using survey questions to identify and learn more about those who exhibit design thinking traits. Design Studies, 38, 92-110. doi:10.1016/j.destud.2015.02.002

9- Blustein, D. L., Barnett, M., Mark, S., Depot, M., Lovering, M., Lee, Y., Hu, Q., Kim, J., Backus, F., Dillon-Lieberman, K. & DeBay, D. (2013). Examining urban students' constructions of a STEM/career development intervention over time. Journal of Career Development, 40 (1), 40-67. doi: 10.1177/0894845312441680

10- Bottia, M. C., Stearns, E., Mickelson, R. A., Moller, S., & Valentino, L. (2015). Growing the roots of STEM majors: Female math and science high school faculty and the participation of students in STEM. Economics of Education Review, 45, 14-27. doi: 10.1016/j.econedurev.2015.01.002

11- Brabrand, C., & Dahl, B. (2009). Using the SOLO taxonomy to analyze competence progression of university science curricula. Higher Education,58(4), 531-549. doi: 10.1007/s10734-009-9210-4

12- Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P- 12 classrooms. Journal of Engineering Education, 97 (3), 369-387. doi: 10.1002/j.2168-9830.2008.tb00985.x

13- Brown, T. (2008). Design thinking. Harvard business review, 86 (6), 84-92.

14- Bulunuz, M. (2012a). Motivational qualities of hands-on science activities for Turkish preservice kindergarten teachers. Eurasia Journal of Mathematics, Science & Technology Education, 8 (2), 73-82. doi: 10.12973/eurasia.2012.821a

15- Bulunuz, M. (2012b, October). Upper elementary school students' understanding of basic physics concepts and the effects of an extracurricular hands-on science program.

Paper presented at the 9th International Conference on Hands-on Science. Azdeniz University, Turkey.

16- Bybee, R. W. (2010). What is STEM education? Science, 329(5995), 996-996. doi: 10.1126/science.1194998

17- Carr, R. L., Bennett, L. D., & Strobel, J. (2012). Engineering in the k- 12 STEM standards of the 50 US states: an analysis of presence and extent. Journal of Engineering Education, 101 (3), 539-564. doi: 10.1002/j.2168-9830.2012.tb00061.x

18- Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, imagination and the fires within: Design thinking in a middle school classroom. International Journal of Art & Design Education, 29 (1), 37-53. doi: 10.1111/j.1476-8070.2010.01632.x

19- Chaimala, F. (2009). Conceptual understanding, scientific explanations & arguments in first year university physics: development and evaluation of an intervention. Unpublished Ph.D. thesis, University of Southampton.

20- Charnley, F., Lemon, M., & Evans, S. (2011). Exploring the process of whole system design. Design Studies, 32 (2), 156-179. doi: 10.1016/j.destud.2010.08.002

21- Chiu, J. L., Malcolm, P. T., Hecht, D., DeJaegher, C. J., Pan, E. A., Bradley, M., & Burghardt, M. D. (2013). WISEngineering: Supporting precollege engineering design and mathematical understanding. Computers & Education, 67, 142-155. doi: 10.1016/j.compedu.2013.03.009

22- Çigrik, E. & Özkan, M. (2012). The effect of multiple models hands-on physics activities on development of children's scientific process skills. Paper presented at 9th International Conference on Hands-on Science, Akdeniz University, Antalya, Turkey.

23- Çimer, A. (2012). What makes biology learning difficult and effective: students' views. Educational Research And

Reviews, 7 (3), 61 -71. doi: 10.5897/ERR11.205

24- Çınar, D., & Bayraktar, Ş. (2014). Evaluation of the effects of argumentation based science teaching on 5th grade students' conceptual understanding of the subjects related to a matter and changes. International Journal of Education in Mathematics, Science and Technology, 2 (1). 49-77.

25- Claesgens, J., Scalise, K., Wilson, M., & Stacy, A. (2009). Mapping student understanding in chemistry: The perspectives of chemists. Science Education, 93 (1), 56-85. doi: 10.1002/sce.20292

26- Colvin, W., Lyden, S., & León de la Barra, B. A. (2012). Attracting girls to civil engineering through hands-on activities that reveal the communal goals and values of the profession. Leadership and Management in Engineering, 13 (1), 35-41. doi: 10.1061/(ASCE)LM.1943-5630.0000208

27- Costa, M. F. (2008). Hands-on science network. Improving science education towards a sustainable development. In Costa MF, Dorrío BV, Michaelides P and Divjak S (Eds.), Hands-on Science (pp 542-545). Portugal: Associação Hands-on Science Network.

28- Cross, N. (2011). Design Thinking: Understanding how designers think and work. Oxford, UK: Berg Publishers.

29- Dillivan, K. & Dillivan, M. (2014). Student Interest in STEM Disciplines: Results from a Summer Day Camp. Journal of Extension, 52 (1), 1-12.

30- Donar, A. (2011). Thinking Design and Pedagogy: An Examination of Five Canadian Post-Secondary Courses in Design Thinking. Canadian Review of Art Education: Research and Issues, 38, 84-102.

31- Dorst, K. (2011). The core of ‘design thinking’ and its application. Design studies, 32 (6), 521-532. doi: 10.1016/j.destud.2011.07.006

32- Dugger, W. E. (2010, December). Evolution of STEM in the

United States. Paper presented at the 6th Biennial international conference on technology education research, Gold Coast, Queensland, Australia.

33- Eisenhart, M., Weis, L., Allen, C. D., Cipollone, K., Stich, A., & Dominguez, R. (2015). High school opportunities for STEM: Comparing inclusive STEM- focused and comprehensive high schools in two US cities. Journal of Research in Science Teaching. doi: 10.1002/tea.21213

34- Enger, S. & Yager, R (2009). Assessing student understanding in science: A standards-based K-12 handbook (2nd Ed.). Thousand Oaks, CA: Corwin Press.

35- Foley, B. J., & McPhee, C. (2008). Students' attitudes towards science in classes using hands-on or textbook based curriculum. American Educational Research Association. Retrieved from

http://www.csun.edu/~bfoley/Foley&McPhee%20AERA08.pdf

36- Gharajedaghi, J. (2011). Systems thinking: Managing chaos and complexity: A platform for designing business architecture. Oxford, UK: Elsevier.

37- Gok, T. (2012). The impact of peer instruction on college students' beliefs about physics and conceptual understanding of electricity and magnetism. International Journal of Science and Mathematics Education, 10 (2), 417-436. doi: 10.1007/s10763-011-9316-x

38- Goldman, S., Carroll, M. P., Kabayadondo, Z., Cavagnaro, L. B., Royalty, A. W., Roth, B.,... & Kim, J. (2012). Assessing d. learning: Capturing the journey of becoming a design thinker. In H. Plattner et al. (Eds.), design thinking research, understanding innovation (pp. 13-33). Switzerland: Springer Berlin Heidelberg. doi: 10.1007/978-3-642-31991-4_2

39- Goldman, S., Kabayadondo, Z., Royalty, A., Carroll, M. P., & Roth, B. (2014). Student teams in search of design thinking. In H. Plattner et al. (Eds.), design thinking research, understanding innovation (pp. 11-34). Switzerland: Springer International Publishing. doi: 10.1007/978-3-319-01303-9_2

40- Goldschmidt, G., & Rodgers, P. A. (2013). The design thinking approaches of three different groups of designers based on self-reports. Design Studies, 34 (4), 454-471. doi: 10.1016/j.destud.2013.01.004

41- Gonzales, P., Guzmán, J. C., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., & Williams, T. (2004). Highlights from the Trends in International Mathematics and Science Study (TIMSS), 2003. NCES 2005-005. US Department of Education.

42- Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). Highlights from TIMSS 2007: Mathematics and Science Achievement of US Fourth-and Eighth-Grade Students in an International Context. NCES 2009-001. National Center for Education Statistics.

43- Gonzalez, H. B. & Kuenzi, J. J. (2012). Science, technology, engineering, and mathematics (STEM) education: A primer. Congressional Research Service, Library of Congress.

44- Heilbronner, N. N. (2011). Stepping onto the STEM pathway factors affecting talented students' declaration of STEM majors in college. Journal for the Education of the Gifted, 34 (6), 876-899. doi: 10.1177/0162353211425100

45- Hirça, N. (2012, October). Can hands on science experiments develop students scientific process skill? A modest proposal for science teachers. Paper presented at 9th International Conference on Hands-on Science, Akdeniz University, Antalya, Turkey.

46- Holloway, M. (2009). How tangible is your strategy? How design thinking can turn your strategy into reality. Journal of Business Strategy, 30 (2/3), 50-56. doi: 10.1108/02756660910942463

47- Hom, E. (2014, February 11). What is STEM education? Retrieved from http://www.livescience.com/43296-what-is-stem-education.html

48- Hook, P. (2015). First steps with SOLO Taxonomy. Applying the model in your classroom. New Zealand: Essential Resources Educational Publishers Limited.

49- Hussain, M., & Akhtar, M. (2013). Impact of Hands-on Activities on Students’ Achievement in Science: An Experimental Evidence from Pakistan. Middle-East Journal of Scientific Research, 16 (5), 626-632. doi: 10.5829/idosi.mejsr.2013.16.05.1310

50- Hutchison, N. (2014). Science education partnerships, annual report 2013-2014, Hands-on, Minds-on science education. Washington: Resource Centre.

51- Jonassen, D. (2006). On the role of concepts in learning and instructional design. Educational Technology. Research and Development 54 (2), 177-197. doi: 10.1007/s11423-006-8253-9

52- Kangas, K., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2013). Design Thinking in Elementary Students’ Collaborative Lamp Designing Process. Design and Technology Education: an International Journal, 18 (1), 30-43.

53- Kazachkov, A. & Kires, M. (2014). Hands-on experiments to develop students' creativity and critical thinking. In Costa MFM, Pombo P & Dorrio BV (Eds), Hands-on Science. Science Education with and for Society (pp. 29-32). Hands-on Science Network.

54- Khadri, H. O. (2014). Planning for establishing STEM education department within faculty of education-Ain Shams University an interdisciplinary model. European Scientific Journal, 10 (28).

55- Kim, K. H., VanTassel-Baska, J., Bracken, B. A., Feng, A., & Stambaugh, T. (2014). Assessing science reasoning and conceptual understanding in the primary grades using standardized and performance-based assessments. Journal of Advanced Academics, 25 (1), 47-66. doi: 10.1177/1932202X14520946

56- Konicek-Moran, R & Keeley, P. (2015). Teaching Conceptual Understanding in Science. Virginia: NSTA Press.

57- Kress, G. L., & Schar, M. (2012). Applied teamology: the impact of cognitive style diversity on problem reframing and product redesign within design teams. In H. Plattner et al. (eds.), design thinking research, understanding innovation (pp. 127-149). Switzerland: Springer Berlin Heidelberg. doi: 10.1007/978-3-642-31991-4_8

58- Lantz Jr, H. B. (2009). Science, technology, engineering, and mathematics (STEM) education: what form? What function? Baltimore: CurrTech Integrations.

59- Lawson, B., & Dorst, K. (2009). Design expertise. Oxford, UK: Elsevier.

60- Lin, H. S., Hong, Z. R., Wang, H. H., & Lee, S. T. (2011). Using reflective peer assessment to promote students' conceptual understanding through asynchronous discussions. Educational Technology & Society, 14 (3), 178-189.

61- Lloyd, P. (2013). Embedded creativity: teaching design thinking via distance education. International Journal of Technology and Design Education, 23 (3), 749-765.

62- Mansor, R., Halim, L., & Osman, K. (2010). Teachers' knowledge that promote students' conceptual understanding. Procedia-Social and Behavioral Sciences, 9, 1835-1839. doi:10.1016/j.sbspro.2010.12.410

63- Means, B., Confrey, J., House, A., & Bhanot, R. (2008). STEM high schools: Specialized Science Technology Engineering and Mathematics secondary schools in the US. Menlo Park, CA: SRI International.

64- Meinel, C., Leifer, L., & Plattner, H. (Eds) (2011). Design thinking: understand-improve-apply. Switzerland: Springer Berlin Heidelberg.

65- Melles, G., Howard, Z., & Thompson-Whiteside, S. (2012). Teaching design thinking: expanding horizons in design education. Procedia-Social and Behavioral Sciences, 31, 162-166. doi: 10.1016/j.sbspro.2011.12.035

66- Mentzer, N. (2014). Team Based Engineering Design Thinking. Journal of Technology Education, 25 (2), 52-72.

67- Miller, D. K. G. (2014). The effect of inquiry-based, hands-on labs on achievement in middle school science. Unpublished Ph.D. thesis, Liberty University.

68- Ministry of Education. (2009). Approaches to building conceptual understandings. Wellington: Learning Media.

69- Mohr- Schroeder, M. J., Jackson, C., Miller, M., Walcott, B., Little, D. L., Speler, L.,... & Schroeder, D. C. (2014). Developing Middle School Students' Interests in STEM via Summer Learning Experiences: See Blue STEM Camp. School Science and Mathematics, 114 (6), 291-301. doi: 10.1111/ssm.12079

70- Moon, J. & Rundell, S. (2012). Bringing STEM into focus. Education Week, 31 (19), pp. 32, 24.

71- Morrison, J. (2006). TIES STEM education monograph series, attributes of STEM education. Retrieved from http://www.psea.org/uploadedFiles/TeachingandLearning/Career_and_Technical_Education/Attributes%20of%20STEM%20Education%20with%20Cover%202%20.pdf

72- Naizer, G., Hawthorne, M. J., & Henley, T. B. (2014). Narrowing the Gender Gap: Enduring Changes in Middle School Students' Attitude Toward Math, Science and Technology. Journal of STEM Education: Innovations and Research, 15 (3), 29.

73- Office of the Chief Scientist (2014). Science, technology, engineering and mathematics: Australia’s future. Canberra: Australian Government.

74- Plattner, H. (2010). D.School Bootcamp Bootleg. Palo Alto, CA: Institute of Design at Stanford.

75- Pombo, P. M. M., Fábrica, C. C. V. A., & Dorrío, J. B. V. (2014). The 11th International Conference on Hands-on Science. Conference booklet, University of Aveiro, Portugal.

76- Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important?. Review of Educational Research, 82, 330–348. doi: 10.3102/0034654312457429

77- Rissmann-Joyce, S., & El Nagdi, M. (2013). A case study- Egypt’s first STEM schools: lessons learned. Kuala Lumpur: Proceeding of the Global Summit on Education.

78- Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of k- 12 engineering standards on the implementation of STEM integration. School Science and Mathematics, 112 (1), 31-44. doi: 10.1111/j.1949-8594.2011.00112.x

79- Royalty, A. (2010, October 20). Design thinking assessment. Retrieved from

http://dschool.stanford.edu/groups/k12/wiki/8d33d/Design_Thinking_Assessment.html

80- Ruby, A. (2001). Hands-on science and student achievement. Santa Monica: RAND

81- Ryshke, R. (2015, March 29). AK12DC Summit 2015: Day 2 learning and sharing. Retrieved from https://rryshke.wordpress.com/

82- Schwab, K. (Eds.). (2014). The global competitiveness report 2014-2015. Geneva: World Economic Forum.

83- Sheppard, S. D., Pellegrino, J. W., & Olds, B. M. (2008). On becoming a 21st century engineer. Journal of Engineering Education, 97 (3), 231-234. doi: 10.1002/j.2168-9830.2008.tb00972.x

84- Sheskin, D. J. (2003). Handbook of parametric and nonparametric statistical procedures. Boca Raton, Florida: CRC Press.

85- Supalo, C. A., Hill, A. A., & Larrick, C. G. (2014). Summer Enrichment Programs To Foster Interest in STEM Education for Students with Blindness or Low Vision. Journal of Chemical Education, 91 (8), 1257-1260. doi: 10.1021/ed400585v

86- Supasorn, S. (2012). Enhancing undergraduates' conceptual understanding of organic acid-base-neutral extraction using inquiry-based experiments. Procedia-Social and Behavioral Sciences, 46, 4643-4650. doi:10.1016/j.sbspro.2012.06.311

87- Tofel-Grehl, C. & Callahan, C. (2014). STEM high school communities: Common and differing features. Journal of Advanced Academics, 25 (3), 237-271. doi: 10.1177/1932202X14539156

88- Toulmin, C. N., & Groome, M. (2007). Building a Science, Technology, Engineering, and Math Agenda. Washington, D.C.: National Governors Association.

89- Trnova, E. & Krejci, J. (2014). Hands-on Experiments in the Formation of Science Concepts in Primary Education. Paper presented at the 11th International Conference on Hands-on Science, University of Aveiro, Portugal.

90- Tsai, C. C., & Chai, C. S. (2012). The" third"-order barrier for technology-integration instruction: Implications for teacher education. Australasian Journal of Educational Technology, 28 (6), 1057-1060.

91- USAID/Egypt (2012, January 23). Science and mathematics model schools program (STM). Retrieved from http://apply07.grants.gov/apply/opportunities/instructions/oppRFA-263-12-000020-instructions.pdf

92- VanMeter-Adams, A., Frankenfeld, C. L., Bases, J., Espina, V., & Liotta, L. A. (2014). Students who demonstrate strong talent and interest in STEM are initially attracted to STEM through extracurricular experiences. CBE-Life Sciences Education, 13 (4), 687-697. doi: 10.1187/cbe.13-11-0213

93- Vekli, G. S. (2013). Summer science camp for middle school students: A Turkish experience. Asia-Pacific Forum on Science Learning and Teaching, 14 (1), 1-26.

94- Viennot, L. (2009). Learning and conceptual understanding: beyond simplistic ideas, what have we learned? In E. Sassi and M. Vicentini (Eds.), Physics Education: recent developments in the interaction between research and teaching, International Commission of Physics Education. New Dehli: Angus and Grapher Publishers

95- Walker, J. P., Sampson, V., Grooms, J., Anderson, B., & Zimmerman, C. O. (2012). Argument-driven inquiry in undergraduate chemistry labs: the impact on students' conceptual understanding, argument skills, and attitudes toward science. Journal of College Science Teaching, 41 (4), 74-81.

96- Wen-jin, K., Chia-ju, L., & Shi-an, L. (2012). Promoting Female Students' Learning Motivation towards Science by Exercising Hands-On Activities. US-China Education Review, 6, 572-577.

97- White, D. W. (2014). What is STEM education and why is it important. Florida Association of Teacher Educators Journal, 1 (14), 1-9.

98- Xie, Y., & Achen, A. (2009). Science on the decline? Educational outcomes of three cohorts of young Americans. Population Studies Center Research Report 09-684. Ann Arbor: University of Michigan, Institute for Social Research.

99- Yilmaz, M., Ren, J., Custer, S., & Coleman, J. (2010). Hands-on summer camp to attract K-12 students to engineering fields. Education, IEEE Transactions on, 53 (1), 144-151. doi: 10.1109/TE.2009.2026366

100- Yurick, K. A. (2011). Effects of problem-based learning with Web-anchored instruction in nanotechnology on the science conceptual understanding, the attitude towards science, and the perception of science in society of elementary students. Unpublished Ph.D. thesis, Florida Atlantic University Boca Raton, Florida.

المراجع العربية

١- أحمد، تفيدة (٢٠١٢). تصميم مناهج المتفوقين في ضوء مدخل STEM (العلوم- التكنولوجيا- التصميم الهندسي- الرياضيات- في المرحلة الثانوية، المركز القومي للبحوث التربوية والتنمية، شعبة بحوث تطوير المناهج.

٢- محمد، بدرية (٢٠١٤، أغسطس). نحو تجربة لتطوير تدريس العلوم بمراحل التعليم قبل الجامعي، ورقة مقدمة للمؤتمر العلمي السادس عشر، التربية العلمية "موجهات للتميز"، دار الضيافة جامعة عين شمس بالقاهرة، الجمعية المصرية للتربية العلمية.

٣- وزارة التربية والتعليم (٢٠١٤، ٢٩ يونيو). الخطة الإستراتيجية للتعليم قبل الجامعي ٢٠١٤- ٢٠٣٠. من

http://planipolis.iiep.unesco.org/upload/Egypt/Egypt_Strategic_Plan_%20Pre-University_Education_2014-2030_Arabic.pdf