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A Comparative Study of Integrated STEM Curriculum in Finland, Singapore and the United States to Provide Recommendations for Iranian Curriculum Planners

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ABSTRACT

The aim of study was to compare STEM integrated curricula in Finland, Singapore, and the United States using a comparatively qualitative method. The United States was chosen because of its education structure diversity and the other two countries were purposefully selected because of their international success in the STEM disciplines. The purposeful sample was selected for collection of data according to the definition of STEM and research goals (n= 52). Data analysis and presentation of results were performed using Bereday's Comparative Method and John Stuart Mill's agreement and difference approach. The first findings showed that all three countries have made their STEM goal to achieve 21st century skills and preparation of skilled workforce. Science and technology centers in all three countries are also in charge of STEM programs. The Finnish method differs from two selected countries due to the lack of STEM special schools and emphasis on participatory learning, in-depth attention to the issue of integration and training of professional teachers in all disciplines. Admissions to STEM schools in Singapore are also stricter than in the United States. Based on the findings, it is suggested to Iranian curriculum planners to pay attention to the integrated STEM - as an approach to the science curriculum- to use equally the capacity of schools, research institutes and science and technology parks for all students.

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1. Introduction

In many educational systems, science education faces many challenges. Some pupils are disinterested in learning the experimental sciences and see no connection between their daily lives and this school subject. Part of this problem is due to the crowded and fragmented curriculum, which causes students to view this subject as a set of facts with broad and practical meaning for them (Harlen, 2015). As the traditional curriculum conveys concepts and topics to students separately and artificially, it causes a sense of futility and confusion in them (Ahmadi, 2011); while to solve real problems, citizens need to learn skills that are interdisciplinary. In the twentieth century the dominant trend in education was based on specialization and discipline-based curriculum and presentation of topics separately, in today's technological world, the frontiers of knowledge are completely intertwined. The astonishing advancement of technology in the present age has demonstrated the fusion of different fields of science and technology in practice. Therefore, the curricula cannot be free from these drastic changes. Along with these fundamental reforms, curriculum planners need to consider holistic approaches to educational design to meet new needs arising from the interests of pupils, job market, and society. One of the new methods to solve this problem is to use the integrated STEM approach. While Integrated STEM means discovering connections between science, technology, engineering and mathematics in order to reflect on how these disciplines work in the real world, the benefits of STEM integration education for students are that they benefit from real-life experiences and hands-on applications that Mirror STEM's professional careers (Gardner, 2017). STEM Integrated curricula provide opportunities for more relevant, holistic, and motivating experiences for learners (Furner & Kumar, 2007).

Historically, the acronym “STEM" which stands for the first letters of the words science, technology, engineering, and math appeared for first time in 2001 at the “National Science Foundation”, United State of America to emphasize the importance of these four disciplines and was quickly adopted by educational administrators (Carter, 2013). Although these courses are still isolated in American schools and taught with minimal collaboration and sharing of content and methods (Honey, 2014), in recent years, different approaches of learning STEM have been taken - from un-integrated to integrated STEM as Meta-disciplinary (Bybee, 2010). Sanders (2009) states that main goal of STEM is to integrate these four scientific disciplines with a focus on solving real-world problems. According to Heil, Pearson & Burger (2013), STEM education typically focuses on problem-solving and project-based learning - to increase students' understanding through application and practice.

Despite the focus of curriculum planners on improving science and math education in the United States, students' scores on international assessments are still low and the workforce for STEM jobs is not provided (Epstein & Miller, 2011). As the dropout rate in basic sciences and engineering became so high the metaphor of the "STEM Pipeline" - dates back to the 1970s – was popular to express concern about the small number of STEM-related professionals and jobs and increasing of educational and economic competition among countries of the world. The term was later changed to "Leak in the STEM Pipeline" by Svinth (2008, p.1). This leak is affected by factors such as type of discipline, gender, ethnic and racial identity, social and economic status, and other factors - given the structural inequalities of American society. For example, women working in the STEM area have been marginalized, and most of these jobs have been given to men (Banning & Folkestad, 2012). Thus, attention to STEM program in the United States has been an attempt to improve the quality of science, mathematics, technology, and engineering education. The situation in Finland is also significant. Although the country excels in the quality of science and math education internationally, in 2019 it announced that despite the high number of IT graduates, the need for the business sector has not yet been met and the training of a specialized workforce, especially among girls should be given more attention (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019).

One of the reasons for these problems is that students in the early years of education are not meaningfully exposed to "STEM" education, and therefore their interest in these topics quickly disappears (DeJarnette, 2012; Kermani & Aldemir, 2015; Moore et al., 2014; 2012). While elementary school is an ideal time for students to become familiar with the “STEM” disciplines because children are naturally curious about the world around them (Aldemir & Kermani, 2016). Elementary and high school pupils become interested in career paths and specific topics based on their previous experiences. Interest in science is often evident before the age of 11, and career aspirations begin at the age of 13 (Archer et al., 2010). This interest leads to a deeper understanding of the concepts of “STEM" by creating opportunities to experiment and manipulate educational materials in the learning environment. The science and attitudes that students acquire at an early age provide basic knowledge for topics that become more abstract and difficult as they continue their education (Keith, 2018, p.12). Since the STEM program takes the experimental and mathematical sciences out of the pure and abstract state - by demonstrating their application in technology and engineering - and provides the background for the attractiveness of education, it can affect students' attitudes about STEM disciplines (Hettinger, 2014). For this reason, the positive attitude and interest of students from top countries in the science has been one of the factors in their success in Trends in International Mathematics and Science Study (TIMSS) (TIMSS Report, 2011) and therefore one of the methods to create interest and a positive attitude towards science - can be the use of STEM integrated programs.

Various studies have shown the positive effect of integrated STEM programs - compared to method of separate teaching of these four disciplines - on students' scientific creativity and academic achievement in mathematics and science (Guzey, et al 2017; Siew & Ambo, 2020; Wade-Shepherd, 2016). The impact of these programs on job identity, students' positive attitudes about science, increased interest in choosing engineering and technology disciplines, and increase interest of study STEM disciplines has also been confirmed (Daugherty ,2010; Mahoney ,2010; Sanders ,2009; Satchwell & Loepp ,2002). Science and mathematics education also faces some challenges in the Iran education system; so that the situation of students in these subjects in TIMSS test indicates that their performance is lower than the global average (TIMSS reports, 2003, 2007, 2011, 2015, 2019). The performance of Iranian pupils shows that their success in multiple choice questions and the knowledge's level of Bloom's taxonomy has been relatively good, but they have a lower range of attention and focus in solving descriptive and complex questions. Also, due to the lack of attention to practical, laboratory activities and process skills in Iran's schools, students are weak in achieving affective and psychomotor objectives (Ghasemi, 2016). Yousefi & Fakhari (2018) consider the partial view about training of science and lack of use of new educational approaches - which seek to establish interdisciplinary communication - as part of the criticism of science education in Iran.

Iranian researchers have also shown more interest in examining these challenges. Kabiri, Ghazi Tabatabai & Bazargan (2017) first determined the qualifications that pupils of Grade eighth should have in science subjects - based on the US and British science curriculum and the documents of international science education institutions. Then they examined the content of the Iran's science curriculum and found that out of 22 competencies extracted, 11 competencies were not considered in this curriculum, such as:

- Knowledge of using scientific tools, performing mathematical operations on knowledge and practical competencies,

- Integration of knowledge, explanation of natural scientific phenomena and critique of others in the competencies of high level concepts,
- Use of models in competence to work with models and diagrams,
- Evaluation of scientific evidence and reasoning in the competence of scientific research, and
- Supporting scientific inquiry along with creating a skeptical view of science in attitudinal competencies

Qualitative meta-analysis of integrated STEM research also reveals that these programs are research-based, project-based, problem-based and design-based as an active teaching and learning strategy. Of course, in some cases these approaches are overlap, although pupils play an active role in all of them (Mustafa, Ismail, Tasir, & Mohamad Said, 2015). Khanjani, Khazaei & Taghipour (2011) and also Danesh pazhouh (2004) by examining the professional qualifications of science, mathematics and biology teachers have come to this conclusion that teachers do not relate these subjects to the real life of students. Instead of guiding students to hypothesize, think scientifically, and solve problems, they try to convey curriculum content to pupils through passive methods. These teachers also had little knowledge of new technologies such as computer science, biotechnology, and information and communication technology. Valizadeh (2014) in analyzing the content of primary school textbooks found that the authors did not pay enough attention to scientific-technological literacy. The findings of Irandegani (2015) in examining the level of process skills in primary school textbooks indicate unbalanced attention to these skills.

Due to the fact that integrated STEM curricula have recently been considered by curriculum planners around the world, less comparative studies have been conducted about it. In Iran, STEM training program is also a new phenomenon and reviewing the experiences of other countries can lead to find ideas for designing it. Accordingly, the purpose of this study is a comparative study of integrated STEM curriculum in Singapore, Finland and the United States to provide solutions to curriculum planners in the Iran’s educational system. In order to achieve the purpose of the research, the following questions are raised:

- What is the status of integrated STEM curricula in selected countries?
- What are the similarities between the selected countries in the integrated STEM curriculum?
- What are the differences between the selected countries in the integrated STEM curriculum?

2. Research Method

The present research is qualitative in nature, practical in term of goal, and comparatively qualitative using meta-analysis approach. Data collection method was documentary and Bereday's comparative method and agreement and difference approach of John Stuart Mill were used for analysis of data and presentation of results. The countries were targeted based on the strategy of "different social systems, similar educational outputs". The statistical population of the study included 250 published studies of the integrated STEM curriculum in the period 2000-2020, including the keywords integrated STEM, integrative STEM. These keywords were searched in the databases of ProQuest, Springer, Science Direct, Sage and Eric. The targeted sample includes 40 articles and 12 PhD. dissertations. The criterion for selecting the research sample were: to define STEM as a combination of at least three disciplines of STEM disciplines, to present the STEM programs in school curricula and activities, and to be related to the STEM programs of the three countries of the United States, Finland and Singapore. In order to increase the validity and reliability of data in the stages of targeted sample selection, data collection and analysis and conclusion, monitoring was performed by two co-authors. Then, the data obtained from the selected researches were reviewed and approved by two professors of curriculum planning in Shahid Rajaei and Kharazmi Universities.

3. Findings

3-1- Description and Interpretation stage

3-1-1- integrated STEM goals in United States

By examining integrated STEM programs such as EiE, IMaST, EBD, PLtW, their goals can be summarized as follows: Creating literacy and competencies of the 21st century; training the workforce with STEM ability; increasing interest of learners in STEM; creating a standard-based program; creating & increasing students' scientific and technological literacy; increasing students' understanding of the four STEM disciplines; increasing the ability of teachers in STEM disciplines; providing STEM learning opportunities for all students regardless of their gender, ethnicity and race; develop a program that provides opportunities for early learning to lead the next generation of United States to become technicians, innovators, designers, and engineers of the future; promote collaborative teaching and learning; providing students with opportunities to learn through hands-on activities with an emphasis on real-life situations (Carter, 2013; Honey & Pearson & Schweingruber, 2014; Satchwell & Loepp, 2002).

3-1-2-Integrated STEM goals in Finland

Since 2003, with the establishment of the “Finnish Science Education Center” (LUMA Centre Finland), the goals of Integrated STEM program include issues such as interest and continuing education in STEM disciplines especially for female students; promoting learning and teaching of STEM in all courses; and support of STEM teachers. Training the competitive workforce and helping to build a sustainable future for citizens are also among the educational goals of the STEM program in Finland (Andreotti, Biesta &Ahenakew, 2014). The Finnish Mathematics and Science Education Research Association (FMSERA) also has determined some goals for the STEM program such as the need to train students as citizens of the world; encourage pupils to understand the four disciplines of STEM; and reduce the gap between STEM skills. In addition, students must be trained to be creative thinkers, technologists, problem solvers, contributors, and future partners (Kennedy & Odell.2014).

3-1-3-Integrated STEM Goals in Singapore

In Singapore, STEM programs have been implemented since 2004 with the aim of providing learning opportunities about real-life situations through hands-on activities. Also, the aim of education is to train people who are familiar with the basic sciences and have scientific-technological literacy so that they can make consciously and rational decisions in their daily lives by understanding scientific facts (Idris, Daud, Meng, Eu, & Ariffin, 2013). In addition, in this country, the logic of why and what should be taught in integrated STEM programs depends on the view of school administration on the needs of society and the industry. Therefore, training specialists in the field of STEM program is one of the goals of science education in Singapore. The goal of the integrated STEM program is for students to find a strong sense of ownership over their learning and its relation to their future job (Teo, 2019). The approach of the “Singapore Institute of Technical Education (ITE)” in technology-based programs is based on a holistic Hands-on, Minds-on, Hearts-on STEM related education. The ‘Hands-on’ training aims to equip students with the required skills-set for employment while the ‘Minds-on’ learning aims to develop them into independent-thinkers and flexible practitioners, equipped to manage rapid changes in the global environment. In addition, the ‘Hearts-on’ learning aims to develop students who have the passion for what they do, self-belief and care for the community and society. These programs provide a comprehensive STEM related education and training, where students integrate theory with practice through coursework, industry exposure, projects and experiential learning (ITE, 2012).

3-1-4- Integrated STEM Curricula in the United States

In the 1990s, after numerous reports (such as the Nation at Risk & Before It's Too Late Reports) about the weakness of science, math, and technology education in the US education system, standards for science education was prepared in two separate documents by the “American Institute of Science (AIS)” and the “National Research Council (NRC)". These documents included standards for technology education, according to which various programs were designed. However, the need for an integrated and interdisciplinary approach to STEM led to the finalization of the “Next Generation Science Standards (NGSS)” in 2013 in collaboration with NRC, the “National Science Teachers Association, (NSTA)” and the “American Association for the Advancement of Science (AAAS)”. These standards include three different dimensions: Core ideas, crosscutting concepts, and practices. In fact, the core ideas are the key concepts that are important in any field of science and are presented in academic courses in a spiral cycle from simple to difficult concepts. These concepts are defined in four areas: Physical science, life science, Earth and Space science and Engineering. Crosscutting concepts help students connect the four disciplines and gain scientific insight into the world around them. They work and explore the core ideas and crosscutting concepts associated through scientific research (Pasley, Trygstad & Banilower, 2016). For example, one of the standards of the next generation in junior high school and in the field of Earth and Space science, which is related to the core ideas, including concepts such as space and stars; the pattern of motion of the sun, moon and stars (observing and describing them through models) and Earth and the solar system (as part of the Milky Way). Crosscutting concepts include patterns, scale, proportion, and modeling that link science, math, engineering, and technology.

Expected practices include modeling the solar system, data analysis, and design solutions. Students should also use technological tools to prepare and explain their model. This model can be conceptual, graphic or handmade. In this example, students become familiar with the force of gravity - as the driving force in the solar system - but it is emphasized that Kepler's laws should not be taught in this stage (Penuel, Harris & DeBarger, 2015). Since the STEM programs originally comes from US, various programs such as IMAST, TSM, PLtW, EiE, AWIM have been implemented based on science education standards and NGSS standards. Here, the EiE program, which is very successful and covers primary school, is reviewed. Engineering is Elementary (EiE): This program is designed by the Boston Museum of Science for elementary school children funded by NASA. EiE mission is to create a generation of problem solvers. It designs STEM learning experiences that surprise, delight, and inspire lifelong learners; encourage all children, including those from underrepresented and underserved groups, to envision themselves as engineers—scientists, mathematicians, biochemical engineers, computer scientists and so much more. The Museum of Fine Arts, Boston holds various courses and workshops for teacher training (MAF, 2022). In this integrated program, the stages are determined based on engineering epistemology:

First, engineering is a social field and operates based on responding to real-world needs (Cunningham & Kelly, 2017; Cunningham & Lachapelle, 2014). Before starting any project, engineers should look at the issue in the context. So every EiE lesson starts with a story so that students become interested in the subject and understand the need to engineer it; set standards and constraints; and relates it to real life (Aguirre-Mun˜oz & Pantoya, 2016). The second step is to use data and knowledge to solve problems and make evidence-based decisions. Engineering issues require pupils to acquire their practical skills through the concepts of mathematics and science (Cunningham & Carlsen, 2014). So when designing an EiE curriculum, teachers need to evaluate what students know and understand, to create an engineering scenario by providing open-ended questions with a variety of solutions that have challenging outcomes appropriate for the age of the children.

The third is problem solving using special tools and strategies such as exploring the properties of materials and building models and prototypes. The most commonly used tools by engineers are engineering notebooks, which allow children to record their thoughts and logic for the use of specific materials or designs and to record the results of group activities (Hertel, Cunningham & Kelly, 2017). The fourth point is to use creativity and innovation. There are usually several different solutions to challenges of engineering design that can sometimes lead to failure. Therefore, the repetitive process of failure and correction of solutions is not considered as a negative result. Students should be taught throughout the program that rethinking ideas and designs, as well as their failure, are acceptable and may provide an opportunity to discover innovative methods. It is noteworthy that the EiE program is designed in such a way that the required training materials are not too expensive and out of reach (Cunningham & Kelly, 2017). An Example of an EiE Curriculum: The engineering design steps and the learning cycle of this program include Ask, Imagine, Plan, Create, and Improve.

In the first lesson, the context is created to motivate students through a picture story that includes a set of questions that make they think more and more. In this story, an Indian girl finds a turtle in polluted water and with her mother - who is an environmental engineer - tries to find ways to filter out water pollution so that they can clean the turtles' habitat. In the second lesson, children gain a broader perspective on what engineers actually do in this area. They are researching technologies that address water pollution. They are also asked to research in small groups the climate pollution in their city. The third lesson is designed to understand the relationship between science, math and engineering. Children research scientific data that helps them make water filters. In Lesson four, students learn the steps of designing and building filter to remove dirty water from soil particles, cornstarch, and tea. In this lesson, each group only researches the filtering of one of these pollutants. Also, each group uses materials as filters - such as cotton, strainer, fine cloth, and sand. They then check how much of each of these filters removes the particles. In the last step, students create a large table of data from all groups. After testing and drawing the table, students are challenged to build a filter with a combination of materials from each group. During the design challenge, students use five-step engineering design: Ask, Imagine, Plan, Create and Improve water filters to best remove particles and paint from dirty water (Hester & Cunningham, 2007).

Figure 1 - Engineering design steps

3-1-5-Integrated STEM curricula in Finland

Integrated STEM curricula were less common in Finnish schools, and had the same place in school education as any other subject. In Finland the number of science and math hours is less than in other countries, but not only the structure of the science class but all the courses - especially in the elementary school - are designed in integration and based on research and problem solving skills. Diverse ICT skills, study skills, and the ability to collaborate between students and interdisciplinary curriculum themes are also emphasized in schools (Su et al, 2017). Finnish teachers are highly professional and learn research skills during their 6 years of study, and a problem-based approach to solving challenging global issues - such as air pollution, global warming and energy - as a basis for establishing relationship between STEM disciplines (Su et al, 2017).

Since 1996, a project namely LUMA (a Finnish word for experimental and mathematical sciences) has been run by the Ministry of Education / National Board of Education project to improve skills in mathematics and natural sciences with the participation of 10 teacher training centers and 24 municipalities. The aim of this project was to make students interested in STEM subjects and its main focus was to promote effective continuing education in these disciplines, e-learning and provision of educational materials (LUMA Support Group, 2002). Following the presentation of the results, the “LUMA Centre Finland” was formally established in 2003 as the " National Science Education Center", which now operates in collaboration with 13 universities. The events planned by LUMA fully support the integrated STEM program and promotion of its disciplines. Examples include science clubs, summer camps, and science day. The main purpose of these activities is to provide positive experiences in children and adolescents towards science, mathematics and technology and interaction with the scientific-academic community. Math clubs held by the University of Helsinki in primary schools use hands-on, sports and games to introduce children to mathematics and motivate those who have difficulty learning this subject. Scientific clubs are formed separately each academic year for pupils of Grades 1-4, and Grade 6-9 in the Chemistry Laboratory. LUMA also holds math and technology science camps during the summer, which are also attended by teachers and teachers-student. The “Millennium Youth Camp” is an international activity that has been introducing students to job opportunities and innovations since 2010 in collaboration with the “Technology Academy Finland” (TAF) in ten subject groups.

3-1-6-Integrated STEM curricula in Singapore

Since 2013, the “Science Centre Singapore” in collaboration with the Ministry of Education, has implemented a new STEM department and applied this programs with a holistic approach of " Hands-on, Minds-on, Hearts-on ". The main purpose of these programs is to prepare students to face new realities and challenges in the global labor market (Seng, 2011). Hands-on means trying to design and build a product, while minds-on means the stages of scientific research and the acquisition of process skills and familiarity with engineering design and hearts-on means creating interest and inspiring students about STEM and creating a connection between knowledge and real life. This program enables 13- 15 year-old students to apply what they have learned in these subjects to solving real-world problems. These comprehensive trainings integrate theory with practice through participation in projects and industry exposure. The program also enables 13-15 year-old students to apply what they have learned on the subject to solving real-world problems. After the workshops, the instructors were present in the teachers' classroom for a few weeks as guides so that they could gain the necessary confidence in teaching.

The instructors and teachers jointly designed the lesson plans in detail, such as scripted lessons, so that teachers could use them in the early stages of teaching. For these courses, formal grades are not assigned, but the students' performance is examined by presenting projects and participating in scientific competitions and exhibitions. Teachers also invite STEM experts to come to the classroom and talk to the children so that learners can become familiar with STEM's applications and community needs (Kmicikewycz, 2018). In addition, each school should design its own integrated STEM program with the help of industry, higher education institutions or other social institutions. In 2018, Singapore's Minister of Education announced that by 2023 all primary schools in the country should have their own integrated STEM program (Tan, 2018). The Science Centre Singapore has developed kids' STOP-enriched programs for children age from 18-month-olds to 8-year-olds. These programs promote education in the form of extracurricular activities in schools along with playing in a safe environment. Robotics and Lego programs are also offered as part of STEM programs in all educational stages.

The Singapore Agency of Science, Technology and Research (A*STAR) and the Singapore Science Center play an important role in the implementation of STEM events. Some of these events are Discover Science Resources, the National Robotics Competition (NRC), the Street Science Festival, the Marketing Science program (MSc), and the Sony Creative Science Award (SCSA). The Discover Science Resources provides many scientific resources, including training kits, small exhibits, and posters for teachers to use in the classroom or at science camps. Each training package is specific to a theme of the school science curriculum. The kits come with various worksheets, instructional videos for teachers, and educational materials for students. In addition to enriched programs, events such as the National Robotics Competition encourage students to develop problem-solving skills, entrepreneurship, creative thinking, and teamwork.

The Street Science Festival, which is a festival that includes the idea of developing one's communication skills through the presentation of science in creative ways, is held in the form of a competition and judging is based on the votes of the audience and the scores of the judges. The goals of this festival are to promote scientific communication, to create more vitality and interest in communication between different sciences, to promote the learning of science in a fun and attractive way. The fascinating “Marketing Science program" also hosts science fairs and handicraft activities in Singapore shopping malls. The Sony Creative Science Award (SCSA) is also a competition for elementary school children to make toys that can be made from any material, but a scientific principle must be followed. These events are sponsored by the Science Centre Singapore (Agency for Science, Technology and Research, 2011).

3-1-7- STEM Schools in United States of America

STEM schools in the United States are divided into three categories: 1) Selected (special) schools that enroll a small number of highly motivated and gifted students in STEM areas; 2) Inclusive schools, which enroll students with diverse social backgrounds but main focus is on attracting students from low-income families, minorities, and other marginalized youth and 3) STEM-centered technical and vocational schools, which help a wide range of students prepare for STEM-related jobs through familiarity with integrated programs. Selected schools admit elite students through a written test. There are currently 90 STEM schools in the country, most of which have been established since 1983, following the publication of the “A Nation at Risk” report. These schools typically have specialist teachers, curricula, and advanced laboratory equipment (Thomas & Williams, 2001). Inclusive schools accept pupils through lotteries and support academically disadvantaged students (Young et al., 2011). The goal of STEM-based technical and vocational schools is to motivate students to learn through real-life programs and to train workers with technical skills. Of course, it is difficult to distinguish between technical and vocational school programs and STEM programs, and these schools are related to all STEM fields (Stone, 2011). In addition to public schools, there are private schools with a focus on STEM and technology education.

3-1-8- STEM schools in Singapore

In this country, all types of STEM-centered schools start operating after the end of primary school. In Singapore, a variety of special public schools have been established under the name

“Direct School Admissions” (DSA-Sec) since middle school. STEM-centered schools with special programs in robotics, aerospace engineering, integrated sciences, mathematics and experimental sciences are among these schools. Student admission is done by reviewing elementary school grades, providing an example of pupil comprehensive skills and abilities, and teacher testimonials that describe the student's skills and personality traits (Teo, 2019). In Singapore, there are schools such as American Selective Schools that select elite students based on standardized tests. For example, in 2005 the National University of Singapore (NUS) launched its “School of Science and Mathematics”, where teachers must have a doctorate or a master's degree. Students in these schools pursue their study under the supervision of teachers and with the help of university professors. In 2010, the School of Science and Technology was established in collaboration with the Singapore Polytechnic, which has put its approach to applied learning with a greater emphasis on ICT. Some schools in Singapore also define their STEM programs for a limited number of students with research-based programs (Aik-ling & Woonfoong, 2014).

3-1-9- STEM schools in Finland

There are no special schools in Finland under the heading of gifted schools or STEM schools. After the primary stage, the technical and vocational training course is designed to improve the skills of the workforce and meet the skills needs (Dobson, 2012).

3-2- Juxtaposition and Comparison

3-2-1- Similarities and differences between goals of integrated STEM training in selected countries

According to Table 1, the main goals of the integrated STEM curricula in selected countries are very similar. The first and most important goal of these countries in designing these programs is to train skilled workers. The second common goal is to create scientific-technological literacy and improve students' technological skills. Since most integrated STEM programs are designed as group projects for students, collaborative learning is another goal of these programs in all three countries. Creating interest in STEM disciplines among all students - not just elite pupils - is one of the fascinating issues that has been addressed in all three countries. In fact, there is a perception in these countries that today all citizens need technological and interdisciplinary skills in their lives. The fifth common goal is to strive to develop the teaching profession because teachers' participation in STEM program, courses and workshops will update their scientific knowledge and teaching methods.

Table 1: Similarities and differences between the objectives of integrated STEM training in selected countries

Goals / Countries	U.S	Finland	Singapore
Training a skilled workforce	*	*	*
Achieve scientific& technological literacy	*	*	*
Collaborative learning	*	*	*
Creating interest in STEM in all students	*	*	*
Teacher professional development	*	*	*
Creating interest in the STEM among girls	*	*	-
Attention to students of racial minorities and low income	*	-	-
Attention to academic achievement in STEM disciplines	*	-	-
Focus on creating standard program	*	-	-

Of course, there are differences between these countries. For example, in the United States and Finland, curriculum planners emphasize the need for girls to become interested in STEM and continue their education in the STEM fields by participating in these programs. In these two countries, the number of female graduates in STEM -related fields is low, and especially in the United States, dropouts and change of fields from STEM disciplines are more common among females. The goals of STEM in the United States are to produce standard STEM-driven programs, to pay special attention to vulnerable and marginalized students, to strive to improve public education in STEM and to improve the scores of American students in International tests have set the country apart from Finland and Singapore. Of course, Finland and Singapore are different from the United States in terms of demographic composition and social issues, and they excel in international exams in terms of general education. In the United States, a large number of standardized and integrated STEM programs have been produced formally and informally in schools.

3-2-2- Similarities and differences of integrated STEM curricula in selected countries

As can be seen in Table 2, there are many similarities among three countries in the characteristics of integrated STEM curricula. In selected countries, for example, organization of content is based on research-based, problem-based, project-based, and design-based strategies. Of course, it should be noted that the support of science centers and academic specialists by the government and municipalities has guaranteed the implementation of these programs formally and informally. In all three countries, there are also training materials, ready-made kits, and resources to support the integrated STEM education, which are also a great help to teachers of STEM.

Table 2 - Similarities and differences of integrated STEM curricula in selected countries

Curricula / Countries	U.S	Finland	Singapore
Program design strategies (problem-based, project-based design-based)	*	*	*
Designing programs by academic specialist with government funds	*	*	*
Use kits and training materials as secondary resources	*	*	*
Presenting programs in summer camps and extracurricular activities in the form of team projects	*	*	*
Support STEM teachers with in-service courses	*	*	*
Preparation of standard programs	*	-	*
Integration as the approach to education	-	*	-
Program design by teachers	-	*	-
Participate in integrated STEM programs as part of the student-teacher internship	-	*	-

In addition, large sums of money are spent on hosting STEM events in all three countries. For example, programs sponsored by the Science Foundation in the United States, national science centers in Finland and Singapore, and some science and technology companies such as IBM (in Finland), Sony (in Singapore), or Siemens and Microsoft (in the United States). In short, extensive programs are provided free of charge to students in these countries, which aim to promote science and technology. For example, from 2013 to 2019, Finland invested 5 million € in the National Science Center (LUMA) to hold STEM events and strengthen math, science and technology education in schools (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019). STEM curricula in all three countries are mostly implemented as extracurricular activities in schools, although in the United States the number and variety of curricula implemented is very high and the next generation of standards - to produce STEM curricula. In all three countries, various competitions are held annually at all levels of education in the field of science and technology, some of which are held at the international level (Finnish competitions). Group activity is also accepted as a basic principle of integrated STEM programs in all three countries.

The stages of group research, product design & manufacturing, and group presentation of results to the classroom or exhibitions are part of these programs. In all three countries, there are in-service programs for integrated STEM training for teachers, although standard programs in the United States and Singapore are more diverse than in Finland. At the same time, the training of professional teachers in Finland has led them to apply integrated STEM disciplines in practice and in the classroom - especially in the elementary school. One of the differences between Finland with other countries is employment of teachers-student graduates in STEM events establishing a close link between the teacher education system and new educational phenomenon such as integrated STEM program.

Finland has one of the best educational systems in the world in terms of highly professional teacher training, a flexible curriculum structure - in which teachers in every district or school act as curriculum designers-, and educational justice - which ensures a high quality of learning in all schools (Sahlberg, 2009). Although in United States and Singapore, STEM has been implemented in various school programs, the key to Finland's success lies in its professional teacher training system. Teachers learn problem-solving and exploratory skills effectively at university (Schleicher, 2012). Finnish teachers, under supervision of professors, learn how to teach research to students. This means that integrated STEM program practically used in the formal school curriculum. If students become aware of how to use the four disciplines of STEM to create innovative solutions, then they will be ready to enter the Stem jobs, an important feature that can be seen in the Finnish education system (Kennedy & Odell.2014). In Finland, students must be able to research, explore different perspectives, collaborate with others, communicate ideas, and act as global citizens (Byker, 2013). All of these are part of the goals of integrated STEM programs.

3-2-3- Similarities and differences between STEM schools in selected countries

Table 3 - Similarities and differences between STEM schools in selected countries

STEM Schools / Countries	U.S	Finland	Singapore
Implementation of programs focused on technical and vocational schools	*	*	*
Availability of special schools after primary school	*	-	*
Admission to selected STEM schools through exam	*	-	*
Admission of low-income students, minorities and marginalized by inclusive STEM schools	*	-	-
Admission to STEM schools through interview and project presentations	-	-	*

The findings of the above table show that in all three countries, STEM programs are implemented in technical and vocational schools, and there is attention to technology, the labor market and relationship between industry and technical and vocational education. In addition to technical and vocational schools, special STEM schools have been established in the United States and Singapore, but Finland, despite not having these schools, is in a very good position in terms of the number of STEM secondary and tertiary graduates (Freeman, 2013). In addition, there are elite special schools in both Singapore and the United States that attract talented students in the STEM area through entrance exams. At the same time, there are other types of schools in both countries that are very different in term of students' admission. STEM-centered schools in the United States are easier to accept and emphasize support for minority and low-income students, while in Singapore, in addition to submitting projects and letters of recommendation from their teachers, pupils also go through the interview process and their school grades are also effective in entering STEM schools.

4. Conclusion

The aim of this study was to compare integrated STEM curricula in Singapore, Finland and the United States to provide solutions for curriculum planners in the Iran's educational system. Given the complex needs of the labor market in the new millennium - such as the training of professional manpower and interdisciplinary specialists in the field of STEM - in recent years, the education system of countries around the world have paid special attention to the development of integrated STEM education. In Iran, integrated STEM programs are still in their infancy and have not been introduced in schools. Therefore, studying and using the experiences of leading countries can help design and implement of these programs in both formal and informal education (extracurricular activities) in Iran. The research findings showed that there are many similarities in the goals of integrated STEM programs in all three countries, which can be summarized as follows:

- Training skilled workers,
- Achieving 21st century skills such as critical thinking, problem-solving, communication and collaboration skills, and high technology skills,
- Developing teachers' professions and providing scientific support in STEM disciplines.

Given its educational, social, and demographic status, the United States has prioritized the following in formulating STEM goals: 1) Attracting racial minorities, vulnerable groups, and low-income groups to integrated STEM programs; 2) Improving the quality of education and improvement STEM disciplines programs in international evaluations; and 3) Focus on creating standard-based programs, which are different from Singapore and Finland. There are three important differences between integrated STEM curricula in Finland, Singapore and the United

States: First, Finland differs from the other two countries in that the integrated STEM approach to education prevails at all levels of education; Second, Finnish teachers design education with more freedom of action and high professional skills without conflict with the usual bureaucracies of educational systems. Third, the Finnish teacher education system also involves teachers-student involved in integrated STEM extracurricular activities and events as part of the internship. These results are in line with the research of Su et al (2017), Dobson (2012) and Schleicher (2012), who consider professional teacher training and freedom of action of teachers and the integrated STEM approach as important features of the education system in Finland.

One of the challenges of implementing integrated STEM approach in the world is how to teach this program to science, math and technology teachers because are trained only in their area of expertise. According to Teo & Ke (2014) STEM approach should be defined as a subject in the teacher training program of these disciplines. Aik-ling & Woonfoong (2014) also believe that teachers should be clearly educated on the topics of engineering design, problem-solving methods, and scientific research methods in order to gain the necessary confidence in the field of integrated STEM program. Finland made possible it through vocational training for teachers-student. Also, STEM schools in the United States and Singapore differ in type of student admission. The Singaporean system takes into account test scores and special conditions for admission, such as interviews, while admission to American schools is easier and sometimes random (Scott, 2009).

Based on the findings of this study, the Iran's curriculum system for determining policies and design of integrated STEM programs can include such things as careful planning, determining the centers responsible for extracurricular activities (such as science centers in the three countries under study), considering adequate funds and participation of academic experts. Specifically, based on the experiences of integrated STEM programs in the United States, it is better to design the next generation of teaching standards such as science and math education standards. Curriculum design should also be prepared to cover all pupils in all schools. In the experience of the United States, attention to less privileged social groups and schools will improve the quality of public education and create equal interest and opportunities in the teaching of the STEM disciplines. The Finnish experience for Iran also contains lessons that focus on the need to change the system of teacher education and prepare solutions to increase the independence of teachers in designing curricula, which can be an important step in the implementation of STEM programs in Iran's schools. According to Finland's experience, Iranian teachers-student can also be used to implement STEM programs as part of their internship. One of the characteristics of the Finnish education system is that the STEM programs are not compactly included in the school curriculum. In Finland, STEM programs instead of being an additional set of standards, is a problem-solving approach to education that connects four scientific disciplines. Strength of the Finnish education system is the emphasis on participatory learning in all areas, including STEM program. The country's education system is notable for the fact that not only do students work together, but there is also enough time per week for a group of teachers to work together to design programs independently (Darling-Hammond, 2009).

The integrated STEM curriculum - known as Applied Learning Program (ALP) - and the teacher support system in Singapore are two valuable experiences for Iranian curriculum planners. Therefore, the implementation of STEM programs should be done by considering the promotion of the scientific level of teachers and by holding training courses - before and during the implementation. A supportive environment must also be created for teachers and students so that they can take risks, fail, redesign and build. These programs should not be an additional burden on the school system programs, so using interested teachers and supporting them and presenting STAM programs as extracurricular activities can be a solution to make students interested in the four scientific disciplines. Just as in Singapore, the mentors team should attend classes for a few weeks as a teacher supporter and participates in the implementation of the lesson plan. It is hoped that this study will be a step to introduce, design and implement integrated STEM curricula in the Iran educational system.

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