This is a postprint version of the article published as:

Ybas, D.,Kurutas, B.S. & Corlu, M.S. (2022). Empowering girls in STEM: Impact of the girls meet science project. School Science and Mathematics. 2022, 122 (5), 247-258

Abstract

Gender equity is a critical agenda for Science, Technology, Engineering and Mathematics (STEM) education to increase women involvement in the STEM pathway. Our study is about the impact of a project in which all-girl teams participated to an educational robotics program. We used quantitative and qualitative data to determine the impact and understand the girls' program experiences. After the program's participation, the mean scores have increased in interest in STEM, interest in STEM careers, STEM identity, and understanding of STEM scales. The groups underlined their problem-solving and group work experiences, as well as, their excitement and motivation related to the STEM activities.

Keywords: Gender equity, girls in STEM, STEM education, STEM project-based learning, educational robotics programs

Yabas, D., Kurutas, B. S., & Corlu, M. S. (2022). Empowering girls in STEM: Impact of the girls meet science project. *School Science and Mathematics Journal, 122*(5), 247-258. https://doi.org/10.1111/ssm.12540

Empowering Girls in STEM: Impact of the Girls Meet Science Project

Representation of girls in Science, Technology, Engineering and Mathematics (STEM) disciplines across all the school levels and workforce became a critical agenda in many countries around the world. 21st century citizens need to have an innovative mindset for the solution of world's complex problems. As STEM teaching-learning activities promises 21st century skills such as creativity, innovation, cooperation and communication, more and more students are encouraged to pursue STEM activities and STEM careers. Therefore, STEM practices are widely included in teaching-learning experiences as early as early childhood education. Based on deeply rooted gender stereotypes, gender equity becomes a critical issue for encouraging girls to join the STEM pathway in early grades.

The gender gap in STEM education in the Turkish context starting from middle grades as it has been also emphasized by researchers. Researchers who worked on the Turkish students' performance in Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) found statistically significant differences in science and mathematics scores in favour of boys at PISA 2009 (Bellibaş, 2016; Dinçer & Oral, 2013; Kılıç et al., 2012). The researchers also indicated that observable characteristics (e.g., family structure or school type) created an advantage for female students in mathematics, but male students were more successful in converting these advantageous characteristics into actual scores. Similarly, the return of studying schools that admit students by examination is 7-8 points lower for girls than for boys (Gevrek & Seiberlich, 2014). Another researcher found that after considering many students' family and school characteristics, Turkish female students lagged male students by at least 7 points in PISA 2015 mathematics scores (Batyra, 2017). The researcher attributed the low performance of girls in mathematics and science to school-based anxiety.

Following from the dropouts from the STEM pathway, women representation in STEM workforce was found to be very low. Although women comprised half of the general workforce in the United States (U.S.), the number of women in STEM professions made up a smaller percentage (Beede et al., 2011; Hill et al., 2010). Particularly in engineering, women hold a disproportionately low share of STEM undergraduate degrees (Beede et al., 2011). Even if, women were better represented in life science, chemistry, and mathematics (National Science Foundation, 2015), only around 30% of all female students selected STEM-related fields, i.e., health and welfare, engineering, manufacturing, and construction, natural sciences, mathematics and statistics, and information and communication (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2017). This small percentage of representation of women in STEM fields implied a significant problem in terms of diversified workforce (Nash, 2017). To achieve a gender balance in STEM studies is also among the main objectives of European Commission (Caprile et al., 2015).

In the Turkish context, authors noted that even though the representation of women in universities and workforce is competitive with regards to the U.S and Europe, covert discrimination still exists. In engineering departments jokes about ‘female inability’ in engineering jobs (Zengin, 2000) and ‘masculine’ and ‘feminine’ divisions were revealed as examples of latent discrimination in engineering faculties (Pehlivanlı-Kadayıfçı, 2019). Similarly in the professional life, some researchers advocated that, women are faced again with covert forms of discrimination. Male dominance in the fields that are prone to advancement and females working in more supportive jobs such as quality and analysis were described as some of the examples (Smith & Dengiz, 2010). Existence of these forms of discrimination will enable the researchers in the Turkish context to examine the gender gap more critically.

Despite the efforts to encourage girls to pursue STEM disciplines and develop interest in STEM careers, national and international studies point out that gender inequality still exists at different educational levels across different STEM disciplines. Globally, studies show that although there is no significant difference in the academic achievement in math and science lessons in early elementary years, as girls move up the education ladder gender gap in performance, representation, interest, and attitudes start to widen (UNESCO, 2017). Some researchers found that female students in middle grades start to think about pursuing potential career paths other than STEM fields (Bieri-Buschor et al., 2014). This finding underlined the importance of understanding what engages female students in STEM areas during and prior to middle school that could help prepare and attract them specifically in STEM-related areas. Encouraging female students to stay in the STEM pathways by STEM programs that empower girls is critical to achieve gender equality in STEM fields. Therefore, there is a need to better understand what engages female students in STEM areas to enter these fields.

Based on this rationale we conducted a study on the project called Girls Meet Science (GMS). GMS project was designed as an all-girls STEM education program, where teams of six girls recruited from socio-economically disadvantaged public schools participated in FIRST Lego League (FLL) Explore program. Selected schools’ access to quality STEM education based on gender equality was limited. The main aim of the GMS Project was to involve more girls in STEM-related activities and to raise awareness about gender equality STEM areas. To achieve this aim, 6-10 years of old female students were supported academically and financially to participate in FLL Explore Program. Through FLL Explore program, positive influence on STEM-related variables was expected to be developed by participating students. In our research, we focused on interest in STEM areas and careers, as well as development in STEM identity and STEM understanding to discover the impact of the project.

Throughout the project, all-girls teams were established. They met weekly under the supervision of teachers and consultants to complete the tasks related to that specific season's theme: Boomtown Build. The tasks led the teams to complete a project focusing on the problems of developing sustainable buildings and cities (Science Heroes Association, 2020). Project-based learning was acknowledged as an appropriate strategy to tackle with problems related to STEM areas (Capraro & Slough, 2013). Engaging students in STEM project-based learning was believed to encourage students to demonstrate STEM-related skills and practice cognitive and social skills that real STEM professionals use (Corlu, 2017).

Purpose of the Study

Even though more women are entering into science and engineering fields today than in previous years (Zhou & Ghao, 2021), the gender gap still exists, and men represent a higher percentage of STEM workforce than women (Botella et al., 2019; Taş & Bozkurt, 2020). Regarding the social and/or family-based roots of the gap, female students need to be exposed to STEM areas within educational contexts, and educators need to find ways to interest female learners. From this perspective, this study explores the impact of a STEM education program named GMS project. To this end, we intend to address following research questions:

(1) Is there a statistically significant difference between the participants' pre- and post-test mean scores of interest in STEM fields, interest in STEM careers, STEM identities, and STEM understanding scales?

(2) How do participants describe their experience throughout the GMS project?

Theoretical Perspectives

Integrated STEM Education

In line with the 21st. century and knowledge society skills, the major focus on STEM education is to raise individuals with innovative mindsets (Corlu, 2012). Innovative individuals find problems, reframe them, propose creative solutions, and build socially constructed products. Integrated STEM education provides students experiences on various cognitive process methods such as project-based learning, scientific inquiry, mathematical modelling, and computational thinking. Cognitive process methods can help the integration of different STEM disciplines. Contexts that include authentic problems of knowledge society help teachers and students engage in cognitive process skills and social products (Yabaş & Corlu, 2021).STEM project-based learning, which is one of the pioneers of the pedagogical STEM approach, has allowed to underline the points of combining disciplines in the context of meaningful problems in STEM education, addressing the development of students' cognitive and social skills, and making STEM education accessible to all students (Capraro & Slough, 2013).

Gender Gap in STEM

It has been pointed out that, equity principle of integrated STEM education underlines that all students, regardless of their gender, academic achievement, and career preferences need to be encouraged to engage in STEM activities (Corlu, 2017). However, girls' participation in STEM activities throughout the school year and beyond was found to be a critical agenda in many countries. UNESCO report revealed that girls' underrepresentation in STEM education is deep rooted and poses a challenge for the progress towards sustainable development (UNESCO, 2017).

Studies from many countries indicated that there is no difference between boys and girls in terms of aptitude and their performance in mathematics in the elementary grades, but the gender gap widens over time (Kijima et. al., 2021). Research also underlined that rather than biological factors, performance in STEM disciplines is influenced by experience and can be improved through targeted interventions (UNESCO, 2017). As this line of research also suggested, girls' disadvantage in STEM education is embedded in social factors and individual learning characteristics. Girls' self-selection bias rooted in gender stereotypes was the major issue that explains how girls lose interest in STEM disciplines. According to the researchers, gender stereotypes which asserted that STEM disciplines are masculine topics and female ability is not suitable to work in these fields also undermined girls' confidence, interest, and willingness to engage in STEM subjects (Kijima et al., 2021).

Loss of interest and motivation to participate in STEM activities in many contexts was also evident in research. Researchers found that, starting from early childhood education, less girls are willing to engage in STEM activities with age, and lower levels of participation are already observed in advanced studies at secondary level (Marginson et al., 2013). Boys also tended to drop out from STEM studies; however, girls started much earlier to lose interest (A.T. Kearney and Your Life, 2016). A longitudinal study in Swedish context showed that career choices were largely formed by age 13, and therefore, it can be challenging to encourage individuals to pursue STEM fields after that age (Lindahl, 2007). Girls' participation in extra-curricular STEM activities such as educational robotics competitions were also reported as low in studies. For example, in the FIRST longitudinal study only 32% of the participants were females (Melchior et al., 2017).

Research evidence showed that increasing various pathways to pursue STEM education promises to facilitate more girls to stay in the pathway. Although their participation rate is low, girls demonstrated more improvement than boys when engaged in STEM activities (Melchior et al., 2017). For breaking the gender stereotypes and making a wide range of STEM career opportunities visible to female students, to promote cognitive process skills as well as social aspects of project process within STEM education contexts were recommended (Benavent et al., 2020).

This background information shows us that programs with supportive learning environments are necessary to improve girls' interest in STEM fields so that they can stay in the STEM pathway. Early year interventions are critical because girls start to lose interest as early as preschool education.

Methodology

This research took place under the scope of the GMS Project. As part of this project all-girls teams from disadvantaged public schools were academically and financially supported to take part in the FLL Explore program. Quantitative data was collected to understand if any statistically significant effect occurred on mean scores of female students' STEM understanding, identity, and interest in STEM careers and fields. Qualitative data was collected to explore what kind of experiences girls went through during the FLL Explore program.

Paradigm emphasis and time ordering were underlined as critical dimensions to determine the mixed method model (Johnson & Onwegbuzie, 2004). We used an equal status and concurrent model for this study that corresponds to convergent parallel mixed method design. In this design, we got the advantage of quantitative data that is more generalizable and qualitative data that explores the details of a phenomenon more deeply. The integration of the results occurred within the discussion section (Creswell & Plano-Clark, 2011).

Research Context

The research was carried out with female students who took part in GMS project of the Science Heroes Association located in İstanbul, Turkey. The association is the program delivery partner of FLL Explore Program in Turkey. For 2019-20 season the association started the project called GMS with the Support Foundation of Civil Society to encourage more girls participate in FLL Explore Program. Owed to GMS Project the Science Heroes Association funded all-girls teams to take part in FLL Explore Program. Teams were recruited from public schools that are accepted as financially disadvantaged. The public schools in Turkey mostly cannot find an opportunity to participate in the programs because of the lack of financial and educational resources. With the help of the GMS Project, Science Heroes Association provided financial support for all-girls teams to participate in the FLL Explore program. All teams received discovery sets and materials to build their project on.

For the educational support the association met with the teams and team coaches (teachers in the same school) regularly, guided them throughout the preparation process and provided technical support and supervision. Under this project all-girls teams participated to the FLL Explore Program and typically conducted following activities:

- Introductory sessions: Teams members introduced themselves and began to work on questions about the Boomtown Build season. They made the LEGO models of the buildings of where they live.
- Discovery sessions: Team members learned about construction sites, professions that work in the construction field (engineers and architects), eco-friendly, accessible, and enduring buildings. They did research and engaged in relevant field visits. Teams worked on LEGO models using what they've discovered about these topics.
- Designing sessions: Team members worked on their innovative buildings. They designed, coded, and built LEGO models to represent their ideas.
- Preparation for the Expo Sessions: Team members prepared a Show-Me poster based on the core values of the FLL Explore program. They've also completed a presentation for the expo.

The teams met on weekly basis using schools' facilities or online platforms. Meetings took place apart from students' regular class schedule and lasted for three months. After the teams completed their projects, they participated in expos in several cities around Turkey. In the expos teams have presented their projects to observers, who are mainly recruited among teachers from different schools.

Participants

The participants of the study were 56 girls in 14 teams that participated to FLL Explore Program throughout the 2019-20 season within the GMS Project. The teams are from various cities in Turkey selected from disadvantaged public schools that had no access to any resources to participate in FLL explore program. Schools were from urban and rural districts. The ages of the girls varied between 6-10 which corresponds to 1st through 4th grade in the Turkish context. This was a first experience to FLL Explore or any other STEM education program for almost all the participants.

Data Collection and Data Analysis

For quantitative data collection, four different scales which were adapted from the scales used in the FIRST longitudinal study of Brandeis University (Melchior et al., 2017). All alpha scores of the scales used based on Wave 1 and Wave 2 baseline survey data, N=1270. Data were analysed with descriptive statistics, and paired sample t-tests.

Interest in STEM fields scale consisted of four items in the scale regarding their interests in Science, Technology, Engineering, and Mathematics (i.e., STEM fields) on a 5-point scale ranging between (1) I am not at all interested - (5) I am very interested. Cronbach alpha coefficient was found as .67 in the reference study. In our study we found the Cronbach alpha as .51.

Interest in STEM careers scale focused on the interest of students in professions related to STEM fields. Students were asked to express their interests in six professions which are scientist, engineer, mathematician, computer / informatics specialist, STEM teacher, and inventor/innovator, on a 7-point scale ranging between (1) Not at all interested- (7) Very interested. Cronbach alpha coefficient was found as .81 in the reference study. In our study we found the Cronbach alpha as .72.

STEM Identity scale included questions targeting students' beliefs in science and mathematics, on a 5-point scale ranging between (1) Strongly disagree- (5) Strongly agree. Some example items from this scale are 'most people can be good at math by learning' and 'being good in science requires an innate ability'. Cronbach alpha coefficient was found as .70 in the reference study. In our study we found the Cronbach alpha as .61.

Understanding of the STEM scale aimed to allow students to express how they evaluate themselves and their future in STEM fields, on a 7-point scale ranging between (1) Strongly disagree- (7) Strongly agree. Some example items from this scale are 'I understand that science and technology can produce unique solutions to the problems in our daily life' and 'I can live a good life as a scientist or engineer.' Cronbach alpha coefficient was found as .94 in the reference study. In our study we found the Cronbach alpha as .90.

For the second research question, focus group interviews were held. Online interviews took about 45-60 minutes. One of the research coordinators facilitated the interviews with teams and if applicable, asked them to share any additional experiences. Audio and video recordings of the interviews were recorded over the online meeting platform. During the interviews, the teams were asked about the details of the projects they prepared for the FLL Explore Program, their online expo and presentation experiences, the information they have learned, and the new experiences they had within the program. 14 teams participated in the focus group discussions. Parents signed an informed consent form for all the data, images and audio recordings collected from the students. The audio / video recordings from the focus group interviews were transcribed verbatim and a qualitative content analysis was conducted.

The elements employed for the trustworthiness of the qualitative data are prolonged relationship with the verbatim transcribed interviews, peer review, member check, and researcher reflexibility.

Qualitative data analysis follows the process of preparing and organizing the data, reducing the data into themes through a process of coding and recoding, and presenting the data in tables or discussion. To not miss out any possible data, any word, sentence, or paragraph that explains a student's experience throughout the project, that part of the quotation used as a unit of analysis (Charmaz, 2006). See Table 1 for identified themes, categories, and codes.

[insert table 1 here]

Findings

Findings for the first research question

Regarding the first research question, is there a statistically significant difference between the pre- and post-test mean scores of the girls that participated the GMS project in interest in STEM fields, interest in STEM careers, STEM identities, and STEM understanding scales? we looked for the difference between the relevant pre- and post-test mean scores of the teams.

Table 2 presents the descriptive statistics of the pre-and post-scales implemented.

[insert table 2 here]

The mean scores of the teams in post-test increased in all scales compared to the pre-test mean scores. To test the statistical significance of this difference we conducted paired sample t-test (Table 3).

[insert table 3 here]

The results of t-tests pointed out that the mean scores of the teams in four of the scales have improved significantly in favour of the post-test ($p<.05$). According to Cohen’s d coefficients the highest effect size has observed in the improvement of the mean scores of interest in STEM scale. The improvement in the mean scores of the interest in STEM scale was followed by STEM identity Scale. The effect size of the improvement in the mean scores of interest in STEM Careers and STEM Understanding was observed as equal. The Cohen’s d coefficients calculated for each scale pointed out moderate to high level of effect.

Findings for the second research question

To find answers for the second research question, “How do participants describe their experience throughout the GMS project? we focused on the cognitive process and social outcomes. The main themes of the cognitive process of participants coincided with the STEM cycline framework (Corlu, 2017). Therefore, we used fact finding, ideation, and product development categories. Regarding social outcomes, groups underlined their attitudes, emotions, and motivation towards the overall process.

Fact-Finding

To describe how they had access to new information, groups underlined the importance of support from teachers, relatives who excelled at STEM disciplines, and research resources for fact finding. Firstly, they heard the announcement about the project via their teachers. Teachers also facilitated the project process and guided the teams during product development. One student expressed her teacher’s support as “I got the most help from my teacher.” Throughout the fact-finding procedure, groups underlined that their relatives (mother, father, uncle, family-friend) who are familiar with the engineering and design inspired a lot to gain ideas and apply them. In one of the groups, many students shared their experiences with their relatives as “I have an engineer aunt. I got information from her”, “My dad helped”, or “I have a civil engineer cousin. I learned from him and designed it together”. Finally, participants shared that various external research sources such as books, and the internet helped them to get new information. One participant said “We searched with the help of the smart phones. When we gathered, they [teachers] already gave us a book and one member read it every day.”

As well as access to new information from different sources, real-life discoveries were one of the key elements of fact finding for participants. Teams claimed that their field trips, discussion with experts in these fields, travel plans, and video watching activities triggered them to make a lot of observations and later this led up to determination of problems as a project idea. Participants agreed that they had various information about professions, and everyday constructions from these discussions and observations. Some exemplary experiences shared by the students are as follows. “We went to the airport. We designed what we saw at the airport with toy Legos”, “They put solar panels not to use electricity, and electricity comes from solar power”, “I didn't know what propellers are for”, “We went to the Provincial Director of Environment and Urbanization. They [architects] made us watch a video. We learned a lot from there.” Finally, in one group, students indicated that their project idea came up from their experiences with their friend in a wheelchair:

> We have a friend, who is disabled and, in a wheelchair, so he cannot climb the stairs or walk. We decided to make a ramp for him; that was a problem. We tried for this. For example, we used the crane as a lift.

Ideation

Regarding the exploration of the problem, groups specifically focused on some agreed-upon problems such as environmental pollution, over-construction, everyday life of people with disabilities, natural disasters, and energy conservation. They proposed that their fact-finding process such as real-life observations, and discussions with experts was very effective in exploration of the problems.

Brainstorming and respectful discussion environment among group members was one of the most underlined elements of the ideation process. According to participants, everybody freely shared their opinions, exchanged ideas, and had the chance to use their imagination thereby joint decisions were made. This was owed to that group members respected every idea, and consensus was reached. They claimed that their interpersonal relations developed during this process. In one of the groups, ideation experiences were shared as follows.

> Everyone explained their opinion while deciding our problems and solutions. And we came up with good ideas and wrote by combining the ideas of all of us. In this group, we all really respected each other. We found our ideas upon the approval of all of us. So, no one was taken against each other. Everyone agreed to everyone's opinion, and we made great results.

Product Development

Regarding the solution development, the most common project ideas were shared as developing systems, and structures for people with disabilities such as building ramps or special elevators to involve them in everyday life and building enduring structures for natural disasters. Moreover, they prepared tools for usage of renewable energy sources such as wind, and sun, and in their projects, they created eco-friendly, recycled, green environments for humans and animals.

Groups were content about collaborative work. They underlined their efforts of working hard for their projects and presentations to succeed. This process helped them to improve their collaboration and social skills. One student shared their experiences as follows.

> We helped each other. I mean, we did not say that this is your department, and we helped each other. For example, a Lego that is missing from it. If I have two, I gave it to her. So, we did it by sharing together. There was no fight between us anyway.

Throughout their project development phase, participants distributed their tasks according to their volunteering and this led them to strengthen their compatibility as working groups. Many of them expressed this finding as “Everyone has already taken their parts willingly, saying I want to do that, I want to do this, and decided.”

Coding

Many participants shared their previous experiences with the Lego play with blocks not with Lego education materials. Besides, some of the participants pointed out their familiarity with some of the coding applications such as Scratch, and Wedo2. Some exemplary statements are as follows: “I normally also like to do something from Scratch and everyone on the team tried to do it on this project”, “I am someone who likes to play with Legos. That's why I joined.”

During the interviews, focus groups were very excited about experiences with a working code. They expressed that writing one command on the computer and creating something by using that command was very gratifying.

> I didn't have any previous experience with coding, but we learned here, we did good things on the tablet, we moved our crane, so we learned coding too. It was very fun. It was very nice to prepare them, listening, and acting were very easy on a person's eye.

Most of the students shared their positive experiences with controlling the codes. One experience is as follows.

> We made a robot. There was a tablet. There were arrow keys on that tablet, pressing them where to go, turning, forward, backward. Crane could also move. Our moving crane also had several cubes. When we turned it, it was pulling the cubes up. If I remember correctly, we used the crane to pull the cubes up. We thought it would be useful for us in construction. We made it to carry things. And we brought them by coding. We also learned to code.

Attitudes, Emotions, and Motivation

Participants shared their motivational, attitudinal, and emotional changes through the project. In what follows, these changes were shared as before and after the project.

Before starting to the project, during the process of selection of participants for the project, teachers played a key role but still many students shared their volunteering for the role. Many of the participants claimed their willingness to succeed and create before participating in this project. One of them specifically proposed her curiosity toward computers, and coding applications: “I wanted to make big things out of little things. I wanted to do something and succeed. Doing such things made me very happy.”

After the completion of the project, the most underlined issue among the qualitative data was participants’ interest and emotion development. Groups precisely underlined their excitement and happiness toward being part of the project, making a presentation about their project, and working as groups. They expressed these feelings as “I was very excited to participate in such a project”, “We were excited. I wondered what will happen, how we will do it, but then when it was our turn, we were very relieved”, and “Mine went very well, I had a lot of fun making the presentation”. They also shared one specific example about the male students who were not even part of the project and how excited they got over the robots.

> When we built that robot… the boys never went out at school or during breaks. They could never take their eyes off that robot. [They said things like] ‘Can I control it, teacher? Can I have the tablet, teacher?’. They never even gave us a chance. They always went to the side of what we did during breaks. We put Legos on the tables, they were always touching those.

Groups shared all these feelings as a positive attitude toward developing their STEM understanding. Some of them claimed that they were not capable of winning any prize for their projects or presentations because they thought that it was not enough. However, they happily mentioned how this idea changed through the project process:

> For example, when our crane moved, we were very happy, relieved because we worked hard to build it, we looked at it one by one and we did it carefully. We hesitated a bit when it didn't work, then we were happy when it worked, that was the difficulty.

> We've relaxed [after the presentation]; it was as if a weight had been lifted from our shoulders. We were proud of ourselves, so we did a great job.

One student shared how her idea for applicability of architecture as a profession changed throughout the project.

> We started this project in the second grade, we were in the middle of it. I decided that I wanted to be an architect when I grew up. One day at school, a fourth-grade boy asked, 'What will you be when you grow up?' I said 'I will be an architect'; He said, 'You can't carry a brick, you're a girl'; I was upset, but then as the project went through, I learned that the architects would not carry bricks, they would design the house, how to be more durable and guide the workers.

Discussion and Conclusion

This study examined the impact of the GMS project and revealed the experiences of participating students. The quantitative results showed that after participation in the FLL Explore Program, students' interest in STEM, interest in STEM careers, STEM identity, and understanding of STEM mean scores have increased significantly. This implies that the girls benefited from the program participation in terms of key STEM related measures. The increase in scores can be associated with students' engagement in STEM practices in an authentic context. According to the effect sizes the highest increase is observed in interest in STEM, which is followed by STEM identity, interest in STEM careers and understanding of STEM scores. To interpret the effect sizes that found in the current study, we compared quantitative findings of most relevant research that studied the impact on various interventions on STEM related variables. Studies that worked on the dependent variables of STEM interest, STEM attitude, STEM self-efficacy, and interest in STEM careers with similar methodology were selected (Table 4).

[insert table 4 here]

The effect sizes of the impact of the participation of all-girls teams in the FLL

Explore Program in the current study is between .70 and 1.03. These effect sizes are higher than most studies examined in Table 4. This shows that girls' encouragement to the participation and completion of FLL Explore Program had a considerable impact on STEM related variables.

Similar to our study, the studies that worked on more than one dependent variable, the highest effect size was observed in STEM interest measures. This finding can be explained with the fact that participation in the FLL Explore Program was most of the girls' first contact with a STEM education program. Even after a short intervention, Kijima et al. (2021) showed girls demonstrated an increase in their overall interest in STEM areas. Studies indicated that out of school STEM experiences have a positive impact on students' STEM interest and STEM attitudes (Baran et al., 2019; Burns et al., 2016). The authors interpreted the positive impact with the authentic context and content integration provided with informal programs (Baran et al., 2019). These elements also existed in the FLL explore program. The participating girls had the opportunity to engage in teamwork and explore STEM practices in an authentic thematic context. Some researchers also articulated that being in contact with individuals of STEM professions (engineers, scientists, designers, etc.) had an influence on the improvement of STEM interest (Baran et al., 2016). Integrated STEM interventions had resulted with improvement on understanding of STEM and interest in STEM careers in other studies (Guzey et al., 2016; Mohr-Schroeder et al., 2014).

It appears that integrated STEM interventions with authentic contexts facilitated a positive impact on STEM related variables such as STEM interest, STEM understanding and interest in STEM careers. Research showed that engaging authentic contexts helped to close the gender-based achievement gap (Silk et al., 2009). The researchers attributed this finding with some of the qualities of the context provided. First, students defined their needs and problems, then designed solutions for the identified problems as real scientists, or engineers do. Cooperative learning and mentoring programs were also found to be effective in terms of developing girls' interest and achievement in STEM areas (Subrahmanyan & Bozonie, 1996). This kind of programs increase the active participation of the females by using learner-centred materials and methodologies (Burkham, 1997). Based on this evidence in research, we can attribute the program's impact to problem-based authentic context, teamwork opportunities, active participation, contact opportunities with real professionals, and engaging in STEM practices.

In the qualitative part of our study, we aimed at understanding students' experience and finding evidence about how they frame their experience in terms of integrated STEM activities. In the fact-finding phase, students underlined mostly the support of their teachers and relatives in terms of gaining specific knowledge about the problem. One explanation for this finding can be that the participants used their social cycle to gain knowledge about their project. Communication with relatives working in STEM fields found to be encouraging for girls to be more engaged in STEM fields (Modi et al., 2012). The girls in our study have consulted their parents, aunts, uncles, etc. who could also serve as role models about specific STEM careers. In the ideation phase, students focused on the problem of the season theme and developed specific solutions about urban planning, accessibility, natural disasters, and energy loss. Students' ideation process on these issues shows that they can create solutions collaboratively about authentic problems of knowledge society, which is a critical skill within STEM practices (Yabaş & Corlu, 2021). We can articulate that season's theme gave participants opportunity to think and find alternative solutions to the 21st century problems.

Girls' appreciation of this problem-solving experience can be explained with their tendency to be involved in professional contexts where they can engage in communal tasks. Researchers proposed that making the community aspect of STEM careers visible had positive impact on female students' career choices (Benavent et al., 2020). Similar research evidence indicated that experiencing the relevance of STEM to the world's problems can motivate more girls to pursue STEM careers (Chubin et al., 2008, Nauta & Epperson, 2003).

Girls' raised excitement, motivation and self-confidence can be resulted from the established link between authentic problems and STEM activities due to the program experience. Ivey and Palozolo (2011) found that girls attributed their increased interest in STEM careers to the creativity and innovation aspects of the implemented STEM program. In our study, the students detailed their understanding about STEM programs after their participation in the GMS Project. They revealed that before the program, they thought the program would be more about coding activities, after the program, besides their excitement about the coding activities they experienced, they saw the STEM programs were more about problem solving, innovation, teamwork, learning and sharing.

Our research provided evidence on the positive impacts of STEM programs that encourage girls to stay in the STEM pathways and increase women representation in STEM workforce. Further studies on different kinds of STEM interventions will help us understand different strategies to reach out more girls to pursue STEM activities and careers. The results from all-girls and mixed groups can also be compared. This will enable researchers and educators to explore the impact on female students within diverse cultures.

Acknowledgement

Authors acknowledge Science Heroes Association for providing the data of the GMS project in writing this research paper.

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Table 1
Identified Themes, Categories, and Codes

Themes	Categories	Codes
Fact finding	Access to new information	Support from teachers, relatives, experts, research resources.
	Real-life discovery	Field trips, discussion with experts, etc.
		Information about Professions
Ideation	Exploration of the problem	Problems: Environmental pollution, over-construction, disabilities, natural disasters, energy loss
	Brainstorming and respectful discussion environment	Exchange and respect of ideas, joint decision, importance of being a team
Product development	Solution development	Solutions: Involvement people with disabilities in everyday life, renewable energy use, enduring structures for natural disasters, eco-friendly, recycled, green places
	Collaborative work	Working hard together, distribution of tasks, cooperation
Attitudes, emotions, and motivation	Before	Willingness to succeed and create Curiosity towards computers and coding
	After	Excitement, happiness, and having fun toward participation, presentation, project, group work, gaining self-confidence
Coding	Previous experience	Wedo, Scratch, Lego applications
	Working code	Product that works with a code

Table 2

Descriptive Statistics

Scale	Time	Mean	SD
Interest in STEM	Pre-Test	15.86	2.72
	Post-Test	18.28	1.78
Interest in STEM careers	Pre-Test	33.06	6.32
	Post-Test	36.74	4.27
STEM identity	Pre-Test	44.41	6.63
	Post-Test	48.52	4.51
STEM understanding	Pre-Test	57.48	13.52
	Post-Test	63.58	9.00

Table 3

Paired sample t-test results

Scale	Time	N	X	SD	t	sd	p	Cohen's d
Interest in STEM	Pre-Test	50	15.86	2.72	5.08	49	.00	1.03
	Post-test		18:28	1.78				
Interest in STEM careers	Pre-Test	50	33.06	6.32	3.46	49	.00	0.70
	Post-test		36.74	4.27				
STEM identity	Pre-Test	44	44.41	6.63	3.58	43	.00	0.77
	Post-test		48.52	4.51				
STEM understanding	Pre-Test	40	57.58	13.52	3.07	39	.00	0.70
	Post-test		63.58	9.00				

Table 4

Effect sizes of STEM interventions' impact on similar dependent variables

Researcher(s) (Year)	Dependent variable	Sample size	Level	Cohen's d
Baran et al. (2019)	STEM attitude	40 (mixed group)	6th	.48
Mayberry (2015)	STEM interest	31(all girls)	7th-8th	.67
Tyler-Wood et al. (2012)	STEM interest	32 (all girls)	4th-5th	1.60
Maiorca et al. (2021)	Self-efficacy	501(all girls)	5th-8th	.49
Melchior et al. (2017)	STEM interest Interest in STEM careers STEM Identity STEM Knowledge	1017 (mixed groups)	5th-8th	.84 .63 .50 .54
Kijima et al. (2021)	Interest in engineering and design Career and future aspirations	97 (all girls)	middle and high school grades	.21-.29 .18-.25