The Practices of Play and Informal Learning in the miniGEMS STEAM Camp

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Abstract

Science, Technology, Engineering, and Mathematics (STEM) play an important role in the educational reform and global economy. However, STEM education lacks the hands-on laboratory in the formal middle school and high school curricula. The widespread gender gap in multiple STEM disciplines causes middle-school aged girls have lower positive attitudes and interests towards STEM fields than male students. In recent years, Science, Technology, Engineering, Arts, and Mathematics (STEAM) education has been viewed as other approaches to increase students' interests and improve study accesses to STEM fields in the United States. The addition of the arts in STAEM education provides more learning opportunities and real-world contexts which meet more students' interests.

miniGEMS 2017 was a free two-week summer STEAM and programming camp for middle school girls in grades six to eight hosted by the Autonomous Vehicle Systems (AVS) Research and Education Laboratory at the University of the Incarnate Word (UIW). miniGEMS was the first free camp with a special focus on engineering and programming in San Antonio. The camp utilized project-based learning curriculum and provided multiple hands-on experiments, field trips, and significant interactions with guest speakers, all of which were designed to increase the middle school girls' interests in STEM-related fields. This paper provides an overview of miniGEMS STEAM camp, motivation for miniGEMS camp, and details on practicing project-based play activities in an informal learning environment.

1. Introduction

1.1 Overview of miniGEMS STEAM Camp

miniGEMS is the first free camp in San Antonio for middle school girls in grades six to eight with a special focus on engineering and programming. The Autonomous Vehicle Systems (AVS) Lab at University of the Incarnate Word has hosted the miniGEMS camp since 2015. The goals of the miniGEMS camp were to introduce more females into the fields of STEM and engineering through robotic projects, computer programming, graphic design, and guest speakers. The camp has an additional emphasis on providing learning and research opportunities for underrepresented communities.

miniGEMS has developed very fast in the past three years. 2015 was the first year when the AVS Lab hosted a free five-day engineering camp. 25 middle school girls from Title I school districts in San Antonio participated the camp. Meanwhile, four engineering research assistants from the AVS Lab and three middle school teachers from the local school districts helped with the daily robotics projects and various competitions. In summer 2016, 26 camp participants were representing different school districts of San Antonio with a special emphasis on recruiting from underrepresented communities. Five undergraduate research assistants from the AVS Lab and three middle school teachers from the local school districts helped with the prior planning and the entire management of the daily camp activities.

In 2017, the camp became a free two-week STEAM (Science, Technology, Engineering, Arts, and Mathematics) and programming camp held four separate times for underserved and underrepresented middle school girls in grades six to eight. The addition of the arts in miniGEMS 2017 provides more learning opportunities and real-world contexts which meet more students' interests. Four two-week miniGEMS STEAM camps were hosted at UIW for a total of eight weeks starting June 5 till August 4 in 2017. Over 114 middle school females and ten middle school science teachers participated. Project Based Learning curriculum was introduced over the two-week camp culminating with a final presentation and skit.

The camp was enriched by various project-based learning activities including environmental sustainability, biologically inspired robots, EV3 Lego Mindstorms robots, control of robots, and computer programming. The participants had opportunities to build and compete using the SeaPerch underwater robots, a unique project aimed at increasing the number of females in engineering. miniGEMS 2017 camp was led by undergraduate and graduate students from various UIW STEM programs including Engineering and Biomedical Sciences. Middle school teachers were hired to participate in the camp. They helped recruit the middle school students from their respective schools. miniGEMS high school student alumni came back as peer mentors for the camp. An End of Summer Conference and Banquet was held for all campers, their parents, and teachers on August 4.

1.2 The shifts from STEM to STEAM Camp

STEAM has been viewed as other approaches to increase students' interests and improve study accesses to STEM in many researches.[1] Students' creative and critical thinking skills developed in arts foster four skills which link to STEM success, including "observation, visual thinking, recognizing and forming patterns, and manipulative ability." [2]

Integrating arts with STEM education has positive relationships with students' academics.[1,2] Specifically, the involvement with music in courses increase students' academic achievements and standardized tests during the middle school and high school years.[3] In ages eleven to fifteen, activities that stimulate right-brain function, such as listening to music, help students' brain development and body integration. By the end of high school, music and other rhythmic activities have a maximum effect on teenagers' brains development.[3]

Although STEAM education increase students' engagements and learning outcomes, there are fewer researchers on STEAM education than STEM education. STEAM programs have many challenges of designing the fifth principles, implementing lessons, and meeting the curricula goals.[1] Therefore, miniGEMS is trying to better integrate and co-teach arts with other STEM activities.

2. Motivation for the miniGEMS Camp

2.1 Issues of Middle School STEM Education

Middle school years is an essential formative and transactional period for students to prepare a fast-changing future and learn foundation skills for a successful STEM careers.[4] However, middle school STEM education is facing several problems, such as policy changes, inequitable disciplines, and lack hands-on experiences.[1,5,6]

House Bill 5 policy made substantial changes to the state's curriculum and high school graduation requirements since it was passed by the state legislature in 2013. The policy requires students who enter in high school to choose an endorsement among five categories in fall 2014: (a) STEM, (b) Business and Industry, (c) Public Services, (d) Arts and Humanities, and (e) Multidisciplinary.[7] The goal for House Bill 5 is to provide students with previous exposure and a coherent course sequence to increase preparedness and sustain interest in STEM careers.

Another issue of STEM education is the inequitable discipline attention.[1] The disciplines of STEM education highly emphasize on science and neglect engineering and computer programming educations in elementary school and middle school. Whereas, engineering education and computer programming have many benefits. Engineering education links the real-world context to the learning of STEM subjects, the ability of problem-solving, communication, and teamwork skills. The application of computation thinking gives rise to opportunities for mathematics education. Therefore, higher recognition, elevation, and attention should be applied in elementary and middle school engineering education and computer programming education.[1]

Lacking hands-on experience is also an issue of middle school STEM education. In STEM classrooms, students are often the passive learners.[8] Instead of learning through practicing real-world knowledge and conversation among peers, students are given some made-up problems and forced to solve the problems. Levine[5] believes the lack of hands-on laboratory time in middle school and high school curricula is because the decreased funding of STEM education and an increased prevalence of standardized testing. To address these issues, there is a need to conduct hands-on projects, developed various methods to increase the time which devoted to hands-on learning, implemented field trips, and science experiments.[5]

2.2 Gender Issues in Middle School STEM Education

Middle school years are important for improving girls' overall persistence in STEM fields. Girls begin to lost interest in science and mathematics during middle school years. It is also the middle school years that females and males achieve and perform differences on standardized STEM test scores and STEM course taking.[10]

Middle-school aged girls present lower positive attitudes and interests towards STEM fields than male students.[9] The study of Dare shows that males maintained a 40% interest in STEM fields throughout high school, whereas females' interests significantly dropped from 15.7% to 12.7%. Girls present lower assessments of their mathematical abilities and large gender difference in spatial skills than boys.[10] Girl's self-efficacy, expectations, and aspirations are easily influenced by the behaviors and beliefs of family, friends, and teachers.[11] Additionally, larger gender differences were founded in STEM career aspirations that males present more interest in engineering, whereas females were more attracted in health and medicine during middle school and high school years.[12] Therefore, many educators are putting efforts to keep girls' interests in STEM during the middle school years. Making some changes to STEM curriculum and STEM pedagogies may help girls better develop their STEM identity.[8]

Based on the issues and gender differentiation in STEM education, Dr. Frye and Dr. Nair began to host MiniGEMS camp since 2015. The camp targeted at girls only and aimed to introduce more females into the field of engineering and improve teachers' awareness of STEM disciplines.

3. Application of Theories in miniGEMS Camp

3.1 Practices of Play and Constructivism Learning Theory

Children's play is essential to a child's development. Play is an active and creative human interaction. Play is also a powerful mediator for learning throughout the middle school and high school years.[13] The play contents involve leadership, social context, imagination, and reflection on social culture.[14] Through play, students develop their minds in negotiation, problem-solving, creativity, and flexibility. Learning through play contributes autonomous thinking and provides opportunities to practice new skills.[14] With social development and technology revolution, learning through play is more focus on meaningful activities. Thus, children's play was a natural occupation of childhood and a vehicle for children's learning.[15]

In miniGEMS, play has many advantages to guide the design of interactive learning environment to increase participants' interests and career aspiration in STEM fields. The design of the interactive learning environment is based on the constructivism concepts and supported with the elements of both interactions with project assistants and hands-on activities. Facilitators in miniGEMS need to facilitate the interactive learning environment and inquire about students' difficulties to avoid misinterpretation. So students can interact creatively with others and reflect on their learning rather than being lectured by teachers.

Participants in the miniGEMS construct their experiences and knowledge through meaningful problem-based and hands-on activities. Learning starts with the students' desire and continues in an active interaction environment. Teachers and program assistants play the roles as facilitators or mentors that improve students' self-awareness, self-efficacy, and interests about STEM fields.

Students are most likely to learn science and construct knowledge when they are engaged and related to real-life experiences. miniGEMS focus on learning through various meaning hands-on engineering and programming actives. Meaningful play activities result in forms of added knowledge, more engagement, and better insight for students. In the miniGEMS STEAM camp, the activities in the camp have a special focus on robotic projects, computer programming, graphic design, and guest speakers. It is also a holistic camp which includes the discussion of the importance of nutrition, education, and empowerment.

Thus, miniGEMS campers learn about science and engineering from the natural world, the presented world, and the virtual world. Through these hands-on activities, management of the learning is shifted from the teacher to the student. Students transfer engineering knowledge and are given free choices in determining their goals for exploration, discovery, and learning.

3.2 Informal and Non-Formal Learning Theory

STEM education has a disconnection between "school" science and practical science which may influence students' attitudes and interests in science and STEM-related careers.[16] Non-formal learning contexts and informal learning experiences on site visits are commonly used strategies to connect school and practical science. Eshach[17] states 85% of students' time spent outside of the classroom. The informal and non-formal learning environments are important to provide out-of-school learning opportunities.

Compare with the formal learning environment, informal learning is less structured, shifts the learning from the teacher to the student, and provides students more learning choices.[17,18] Informal learning experiences occur in museums and science centers where give students better understanding of science.[19] However, non-formal learning occurs through various informal learning contexts and usually has some prearrangement situations which led by teachers or guides.[16] Non-formal learning is planned but highly adaptable in learning places.[17] Furthermore, non-formal learning has the characteristic of being mediated with formal education, but the learning motivation may come from learners' internal factors.

According to Piaget's childhood cognitive developmental stages, middle school students have abilities to get logic reasoning and hypothesize about something that they haven't learned specifically.[20] Middle school students' learning starts with the whole concepts rather than concrete forms. In this period, sciences teaching should focus on the significance of research and discovery rather than memorization and repetition.[21]

Non-formal and informal learning provides effective environments to influence learning and student development. These settings will be instrumental in the STEM education reformation.[22] Non-formal learning provides structured learning and prearranged supporting activities, assisting with other teachers, leaders, or assistants.[16] Whereas, informal learning occurs through student curiosity and group interactions. Therefore, informal and non-formal learning environments in miniGEMS provide effective environments to influence learning and student development. The benefits of an engineering-focused informal learning environment in miniGEMS promote students' awareness of the engineering, provide academic enrichment, have trained and competent instructors, and engage students' participants.

4. Summary

The STEM education reform needs to attract a larger and more diverse student population to STEM fields. miniGEMS as an ongoing STEAM camp is putting efforts to keep girls' interests in STEM during the middle school years, introduce more females into the field of engineering, and improve teachers' awareness of STEM disciplines. Currently, miniGEMS 2018 is planning and recruiting for the upcoming summer. We are exploring how to grow the number of camps and how to better integrate music in the program. By applying play theory and informal and non-formal learning theory, the AVS Lab can host to have a more significant impact on the San Antonio community.

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