An explorative case study on effects of a makeathon for SDGs on middle school students learning and democratic empowerment

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***Abstract*—This paper presents an exploratory case study of a Makeathon program called STEAM for Social Good, designed to empower middle school students in India. The program design was based on a set of three design principles developed by the IEEE Pre-University STEM Education team. Students were taught creative problem-solving techniques for addressing societal problems. They learned to design IoT-based prototypes and Android apps. Thirty-four students attended the ten-day training program and participated in the two-day Makeathon in ten teams. Our results show that the program helped develop children's competence in physical computing and app development and enabled them to apply their knowledge to create innovative working prototypes for sustainable development goal challenges. They learned to work with material and time constraints and create working prototypes from concept to completion during the Makeathon. Overall, the children were more confident as students after the program and saw how technology could make a difference.**

***Index Terms*—K-12 STEAM education, STEAM-based social problem solving, UN SDGs, engineering design process**

I. Introduction

There is growing pressure on school students today to thrive in a knowledge economy constantly reinventing itself. They need to learn to adapt to new digital technologies continuously, develop mental flexibility to embrace challenges as opportunities and innovate local technological solutions for global problems. While, on the one hand, adapting to change is imperative to survive in this fast-changing world, on the other hand, school systems do not adequately prepare children to think outside the box, learn by doing, and create innovative and disruptive solutions. Dr Tony Wagner outlines seven critical skills students today need for life in an interconnected world that are not being taught in schools [1]:

- Critical thinking and problem-solving
- Collaboration across networks and leading by influence
- Agility and adaptability
- Initiative and entrepreneurialism
- Effective oral and written communication
- Accessing and analyzing information
- Curiosity and imagination

To acquire these critical skills means that children must learn to ask good questions, to understand that there are no correct answers in the real world of work and life, to sift through large amounts of information, synthesize them and tell what is critical and what is not, to make their own decisions, to work in teams, to become proactive self-starters, and to write with focus, energy, and passion. Schools also need to provide democratic empowerment wherein children are moulded into thinking citizens of a community, where they are taught about responsibility and citizenship, and they learn to present ideas on sustainable development. Children have spoken out in international forums about their need to become instruments of sustainable development and not just beneficiaries of it [2].

While the systemic change in the school education system in India would need a decade-long runway, the process can be accelerated by exposing school students to hands-on Science, Technology, Engineering, Arts, and Mathematics (STEAM) interventions founded on engineering design processes applied to sustainable development problems. With this goal, we conducted a Makeathon challenge for middle school students in Kochi, India, to introduce children to designing and prototyping digital technology solutions for United Nations Sustainable Development Goals (UN SDGs). We called this program STEAM for Social Good. Since students were selected primarily from under-represented sections of society, they did not have prior exposure to physical computing technologies.

Hence we conducted a forty-hour training program on the Internet of Things (IoT) and Android app development before the Makeathon. In this short paper, we share our experiences and initial results from this intervention's impact on children's empowerment from the lens of learning and competence development and children's democratic empowerment.

Kinnula et al. discuss a tool for educators to use to evaluate their digital technology design and make projects with children in terms of different forms of empowerment [3]. From the framework they presented, we explored the impact of our program by asking the following research questions on children's empowerment:

- How much did the program contribute to children's empowerment as learning and competence development so that they can fully participate in society and reach their full potential?
- How much did the program contribute toward children's democratic empowerment so that children see that engineering and technology can make a difference?

II. Prior work on STEAM Makeathons

The ten-day STEAM for Social Good program was modelled on a prior workshop conducted by AMMACHI labs, Amrita Vishwa Vidyapeetham, in Bangalore, India, in 2019. Twenty-five underprivileged children with minimal prior technology literacy were taught to create technological artefacts that are socially relevant. Researchers noted that the participants developed higher-order thinking skills at the end of the workshop, and the program also enriched their creativity and imaginations [5]. Children learned to rethink and re-scope design possibilities they could construct in two days. They learned to divide tasks, resolve differences, teach each other skills and work collaboratively to complete their prototype. They practised pitching their ideas to judges succinctly yet powerfully. These experiences formed powerful images for the children of how technology can effectively improve people's quality of life.

In 2021, the IEEE Education Society Kerala Section conducted a week-long technical education program named Rural School Technical Enhancement Program (R-STEP) for school students of grades 11 and 12 studying in rural regions of Kerala, India. IEEE Education Society volunteers taught these technologically underexposed high school students the basics of IoT, Robotics, Web Development, and C programming. Students were invited to showcase their projects at the end of the program. IEEE volunteers observed that the high school students showed a remarkable capacity to develop technology literacy in a short span of time [4]. We brought all the learning from these prior interventions into the STEAM for Social Good program.

III. STEAM For Social Good Makeathon structure

The IEEE TryEngineering funded STEAM for Social Good program was conducted in September 2022 by the IEEE Education Society Kerala Section, in collaboration with IEEE SIGHT Kerala Section and AMMACHI labs, Amrita Vishwa Vidyapeetham. It was conducted as a five-day offline training on IoT programming and hardware prototyping, five days of online training on app development, and a concluding two-day Makeathon competition (see Fig. 1 for the program structure). The program targeted middle school students in grades 6-9, especially from underprivileged communities and vulnerable sections of society in Kochi, Kerala, India. We carefully weaved in United Nations Sustainable Development Goals (UN SDGs) along with digital and physical computing education to give the children a unique mix of training emphasizing social and community problem-solving skills and cutting-edge technical skills. The goal was to empower children to develop a "can-do" mindset necessary to develop technological solutions for societal problems. The two-day Makeathon challenge that followed tested their learning and creative thinking abilities to design meaningful prototypes for UN SDG challenge statements. Fig. 2 shows the different challenge statements we gave to the children for the Makeathon.

Fig. 1. The Program Structure

IV. Methods

To answer the research questions, we used an impact evaluation scale that the IEEE Educational Activities Board has designed based on a set of design principles developed over IEEE's Pre-University STEM Education Theory of Action [6]. The three design principles are:

- Design Principle 1: The program demonstrates how engineering and technology can make a difference

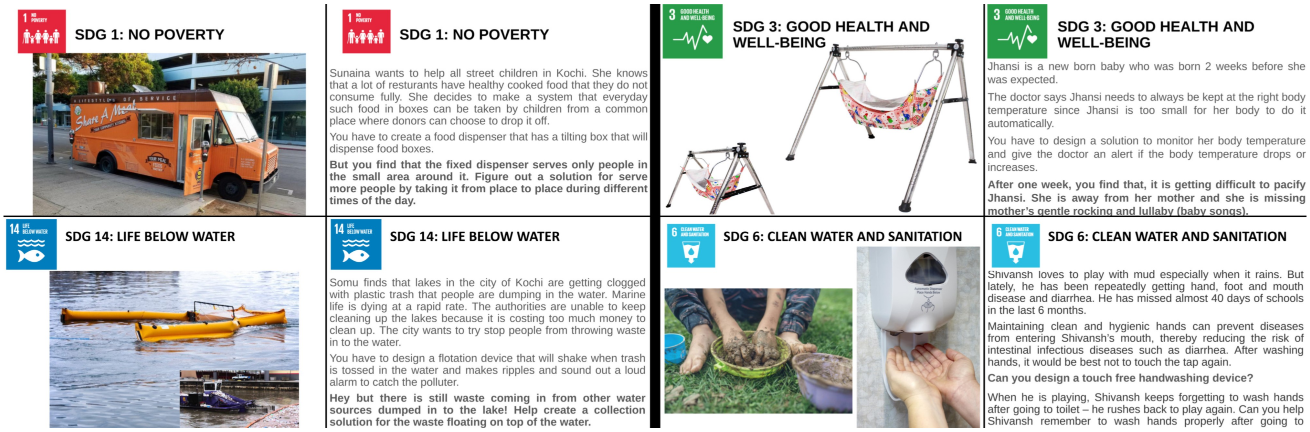

Fig. 2. Different SDG-based Makeathon challenge statements that were given to the students for the 2-day Makeathon

- Design Principle 2: The program targets populations underrepresented in the technical professions
- Design Principle 3: The program has high-quality design and content

We also measured the foundational activities for the Theory of Action:

- Meeting STEM Professionals
- Engaging in hands-on design challenges
- Learning technical skills (e.g., coding, electronics, etc.)
- Seeing career pathways
- Learning non-technical engineering habits of mind
- Participate in solving real problems

We translated the scale from English to Malayalam with the help of two native translators. The different translation transcripts were then compared to develop the best-translated version.

As we had done in our previous research [7], we used the Stages of Adoption of Technology (SA) instrument [8] to evaluate children's progress in adopting new technologies. The six steps of the SA instrument are as follows:

- Stage 1: Being Aware
- Stage 2: Acquiring process knowledge
- Stage 3: Comprehending how the process is applied
- Stage 4: Comfort and assurance
- Stage 5: Contextual adaptation
- Stage 6: Innovating in new circumstances

At the beginning and three months after the program, we asked the children to select the stage of adoption that best reflected their knowledge level of cutting-edge technologies, such as the internet of things and app development. We also asked the children to fill out the IEEE impact evaluation scale. We added an item to the scale, "I am more confident as a student now", to assess the change in the self-confidence beliefs of the students.

V. Results and Discussion

Thirty-four students from fifteen semi-urban and peri-urban schools participated in the ten-day IoT and app development training program. Students learned about seventeen Sustainable Development Goals and mapped the social problems they saw around them to the SDGs. Using IoT and app development skills, they learned to create prototypes for the problem statement they chose to solve. A thirty-member mentor team, including IEEE student volunteers, IEEE young professionals, and three IEEE TryEngineering STEM Champions, mentored the children during the ten-day training program.

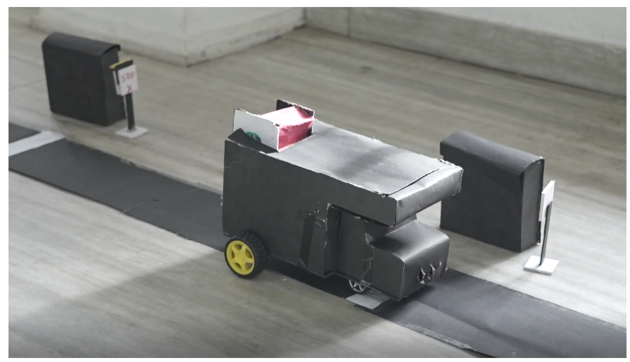

Fig. 3. Prototype made by the students for the SDG 1 problem statement

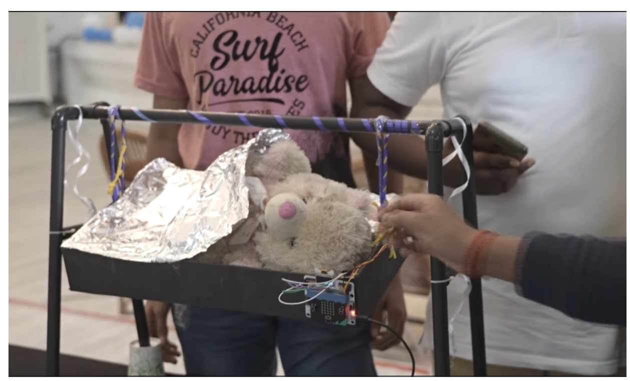

Fig. 4. Prototype made by the students for an SDG 3 problem statement

For the two day Makeathon, forty-three students (10 girls and 33 boys) participated in ten teams. The student teams made ten physical prototypes in the two days of the Makeathon on four design challenges (shown in Fig. 2). Five physical prototypes the children built were working prototypes. Fig. 3 shows a working prototype of a food dispensing truck that the children built for the Makeathon challenge statement in Fig. 2 *SDG 1: No Poverty*. Fig. 4 shows another working prototype of a temperature-controlled cradle that the children built for the Makeathon challenge statement in Fig. 2 *SDG 3: Good Health and Well-being*.

Since some students did not complete the program and some students joined midway into the program, we present the results based on 26 students who completed both the pre and post-program survey after three months of the program. Based on the survey, we plotted the radar plots shown in Fig. 5 on the perceived improvement in IoT and Android app development competence and knowledge level. As is evident from the shaded regions in red and blue, there was a significant increase in the overall knowledge level of the students in both IoT and app development. Independent samples t-test showed that there was a statistically significant difference between the knowledge level of IoT pre-intervention (2.08 ± 3.43) and post-intervention (4.19 ± 3.6), t(50)=4.07, p¡0.001 and knowledge level of app development (1.54 ± 2.5) and post-intervention (3.92 ± 4.79), t(50)=4.5, p¡0.001.

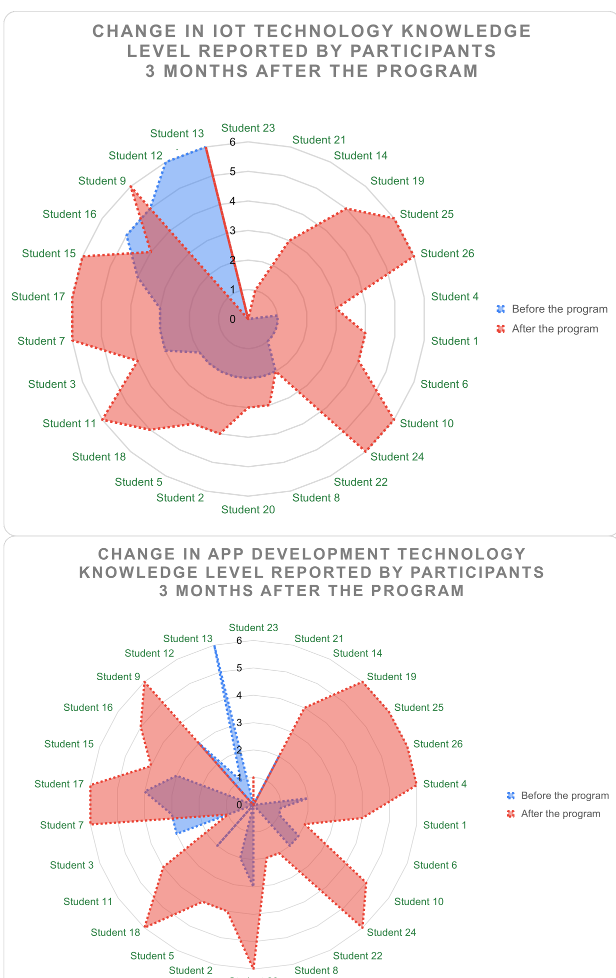

Fig. 5. Change in technology adoption

As shown in Fig. 6, the children agreed or strongly agreed that through this program, they learned how technology positively impacts people and communities. They learned how engineers and technical professionals impact society through their work and saw how children with very different backgrounds (rich, poor, girls, boys, children of any religion or speaking any language) could be engineers and technical professionals. In this program, they stated that they had choices in what they could learn and got to choose partners/teams during learning. They said that all the adults [mentors and teachers] who interacted with them were friendly, the other participants in the program were friendly, they had multiple opportunities to interact with adults and peers, and there were enough adults for the number of students. Most children also agreed or strongly agreed that they were more confident as a student after the program, as shown in Fig. 7.

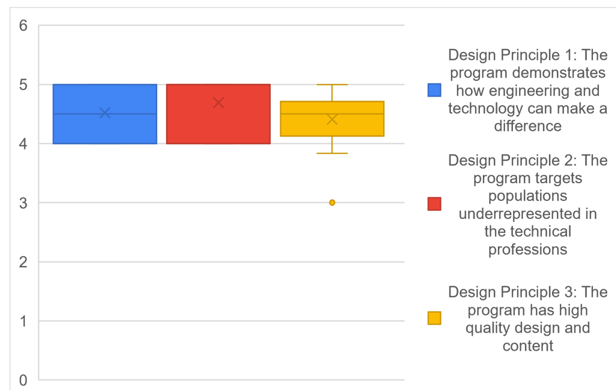

Fig. 6. IEEE Design Principles

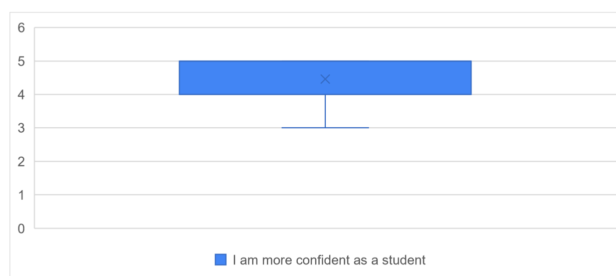

Fig. 7. Confidence of students

With regards to the activities they did during the program (shown in Fig. 8), children agreed or strongly agreed that they worked on a real-world problem of societal importance, and worked on solving the UN Sustainable Development Goals (UN SDGs). They said they had an opportunity to lead, work in teams, and collaborate on their project. They got a chance to meet someone who worked in the STEM field. They learned to make something [hands-on], learned new ways to solve problems, learned about electronics hardware and software, learned something about different branches of engineering, and learned how they could become STEM professionals.

Looking into the learning impact of the students in terms of how much the children applied each of the skills that was taught to them during the Makeathon, as shown in Fig. 9, 80% of the teams applied both app development and IoT skills and 30% of the teams applied just the IoT skills. During the Makeathon, the children picked up a few skills as needed for their projects such as working with drilling machines, soldering etc. This shows that once children develop competance for tinkering with technology, they are motivated to learn new skills on an as needed basis (based on their solution).

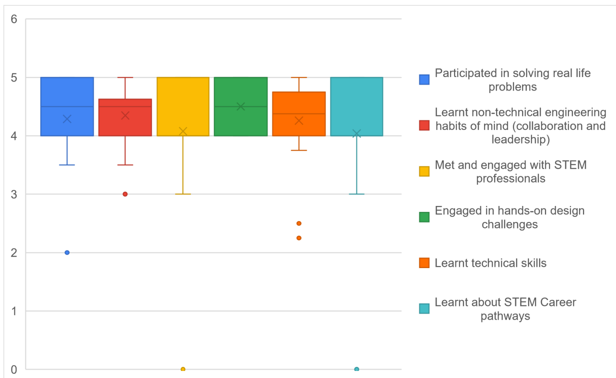

Fig. 8. Children rating of the different program activities that were designed based on the theory of action

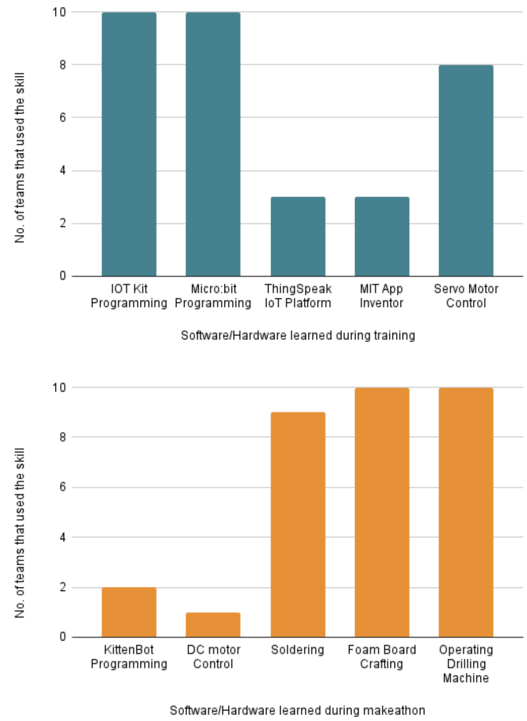

Fig. 9. The top bar chart shows the skills the children used in their projects that were taught to them during the 10-day training program. The bottom chart shows the skills the children learned during the makeathon.

In the feedback form, one child wrote, "Through this program, I realized that technology is not just for entertainment but also to solve basic problems of common people." Another child said, "The program STEAM for social good had a significant impact on many of us (including me). The program helped us to learn more about IoT. We also had a great time with the mentors and the students. The best [thing] about the program STEAM for social good was that it made us think and do something useful for society and the people." Yet another child wrote, "It was a good experience. I got an opportunity to learn to program. I had a good interaction with everyone. I had the opportunity to participate in the marathon. I hope that IEEE will conduct a programme like this again."

These results provide evidence that the program contributed towards children's empowerment both in learning and competence development and towards children's democratic empowerment by helping them see that technology can make a difference.

VI. Conclusion

STEAM For Social Good program set out to provide technology education for social good through the engineering design thinking process. It aimed to empower and inspire children to become innovators and technology creators by providing hands-on experiential learning through research, digital tinkering and making. The program was designed to promote inclusivity by equally emphasizing girls and boys from different socio-economic backgrounds to participate in the program in mixed group projects.

The evidence provided in the paper above shows that the program met its goals and empowered children to be technology creators and innovative social problem solvers. Students increased their understanding of sensors, actuators, and embedded hardware and their appreciation for IoT technology and physical computing in problem-solving. In 2023, we plan to replicate this program in different regions of Kerala to benefit more pre-university school students.

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