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Work in Progress: Development and Implementation of an After-school STEM Curriculum for Kindergarten to 4th Grade Students at Girls Inc. through the "Cummins Powers Women" Initiative

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Abstract

As part of our commitment to achieve gender equality and eliminate the barriers that hinder the advancement of girls and women in the communities we serve, Cummins Inc. developed the "Cummins Powers Women" initiative in 2018. Through this initiative, Cummins has partnered with non-profits from around the world such as Girls Inc. in North America and RISE UP in South America, Africa and Asia to establish programs focused on teaching and mentoring young women and girls, encouraging entrepreneurship and providing leadership training. One such program is the "A World in Motion" (AWIM) after-school STEM Curriculum that Cummins employees have developed for Kindergarteners to 4th Graders in collaboration with the Society of Automotive Engineers (SAE) and our community partner Girls Inc. of Johnson County. Through this after-school Project-based Learning (PBL) program, we aim to inspire young female students in kindergarten and elementary school to pursue a career in the STEM fields by exposing them to simple, age-appropriate engineering projects such as building a jet-toy cart and designing and testing a skimmer. Since its conception in 2019, this program has served about 150 to 200 girls from Kindergarten through 4th grade in the Franklin, Indiana school district. This work-in-progress paper will describe in detail the specific objectives of the AWIM program, the curriculum development strategy, and outlines our future plans to assess the effectiveness of the pedagogies employed in achieving the program outcome of encouraging young women to continue developing their science and engineering skills and eventually gravitate towards STEM careers.

Introduction

While the United States has in the past been a pioneer in the development of technological marvels and engineering breakthroughs, in today's day and age, there is a shortfall of qualified professionals taking up careers in the Science, Technology, Engineering & Mathematics (STEM) professions. According to the 2009 report from the National Assessment of Educational Progress [1], the proportion of students who are proficient in Science drops from 32% in 4th grade to 21% in 12th grade, leading to a lesser than desired proportion of students planning to pursue STEM majors in college. This number further dwindles during college years, as surveys have found that 1/3 of the students in engineering plan on switching majors before graduating [2]. This problem appears to be further exacerbated for women; although the ratio of girls to boys leaving high school who are adequately prepared to pursue STEM degrees in College is roughly equal, the number of females who graduate with bachelor's degrees in STEM fields, especially in fields such as Physics, Engineering and Computer Science, is only 20% of the total number of STEM graduates [3]. Considering the fact that this 20% proportion is part of this smaller group of only 21% of 12th grade students of both genders being considered proficient in Science, it is evident that the pipeline of potential women engineers is inadequate to address the underrepresentation and workforce shortage challenges in STEM fields.

To help address this shortage, it is necessary to develop & implement solutions that empower females and build confidence in them to pursue STEM careers. In this regard, Cummins Inc., one of the US' and the world's leading automotive manufacturing companies, kicked off "Cummins Powers Women" (CPW), a new Community Involvement initiative on International Women's Day in March 2018 [4]. The CPW initiative strives to achieve gender equality by partnering with non-profits such as Girls Inc. in North America, and RISE UP in South America, Africa and Asia to develop educational programs that teach and mentor young women & girls, encourage entrepreneurship and provide leadership training. One of the critical thrusts of this initiative is the "Equality of Opportunity in Education", which aims to achieve gender equality in education of women, particularly in STEM fields to help bridge the achievement gap. A specific program that has been developed by Cummins employees in partnership with Girls Inc., and the Society of Automotive Engineers (SAE) is the "A World in Motion" (AWIM) after-school STEM outreach for female students from Kindergarten to 4th grade in the Franklin, Indiana School District. This work-in-progress paper will cover the background behind starting the AWIM program, the expected outcomes and objectives of this program, the curriculum development process, as well as our future plans to assess the effectiveness of the teaching methods being used in building the confidence of young girls to succeed in STEM subjects.

The paper starts with an introduction about the AWIM curriculum, and why this particular curriculum was chosen, followed by a description about the curriculum material and the instructional techniques that have been employed by the participants in the program. Finally, the paper will detail the potential steps we plan to undertake to evaluate the effectiveness of this program for continuous improvement.

Background on SAE's A World in Motion Curriculum

Over the years, K-12 STEM Outreach has been gaining importance among the Engineering community as a multi-pronged initiative to address two major challenges facing STEM fields: the lack of a strong foundation in Science and Mathematics among school-going students, and the apparent limited interest in STEM subjects among students [5]. K-12 Outreach can help rectify the aforementioned problems by exposing students to relevant topics in a timely fashion in their school years to help drum up interest in said topics, as well as establish some level of competency in basic STEM concepts [6]. STEM Outreach can come in many forms, but one of the most effective methods of said outreach has been the Project-based Learning Method (PBLM). Previous studies have demonstrated that PBLM teaches students to actively utilize skills from various disciplines/fields of study rather than a passive learning method such as listening to lectures or completing worksheets, thereby improving learning outcomes [7-9].

The "A World in Motion" (AWIM) curriculum is one such STEM outreach curriculum that incorporates the Project-based Learning Method (PBLM) Framework [10, 11]. Developed by the Society of Automotive Engineers (SAE) Foundation, this curriculum comprises multiple STEM project modules aimed at different grade levels from Kindergarten to 8th Grade that require students to work together in teams to solve a design problem. Modeled on real world engineering teams, each student in a project team of 3 to 4 members takes on the roles of project engineer, test engineer, etc. with clearly defined objectives and instructions pertaining to their role. Examples of projects that students work on include building and evaluating the performance of a Fuel Cell Car, designing and building a skimmer, applying nature-inspired designs such as floating seed mechanisms to develop rotors and parachutes, etc.

There are a number of reasons the AWIM curriculum was chosen for Cummins' STEM Outreach Efforts at Girls Inc.:

i. Each project/challenge in the AWIM curriculum is very well-organized, with clear step-by-step instructions and prompts for each step in the challenge, along with an emphasis on the scientific or mathematic principles that should be the students' takeaway from the activity.

ii. Professional, high quality training of the volunteers by the SAE staff that developed the curriculum during the initial stages of the program that allows volunteers to take over later as trainers for future volunteers.

iii. Sustainable from both an environmental and cost perspective. Most of the challenge kits developed can be reused multiple times, thereby only requiring an initial upfront investment to purchase the kits. Even for kits that are once use only, it is possible to replenish the supplies at a very low-cost from Big Box stores.

Although the AWIM curriculum selection occurred before the COVID-19 pandemic, another advantage we noticed with the AWIM kits was that during the pandemic, when Cummins employees were required to work from home, it was very easy for us to transition to virtual learning

to allow Cummins employees to provide virtual instruction to the students smoothly over Zoom. This was due to the versatility of the kits and lesson plans that could be customized easily without much effort to allow virtual learning that did not require the presence of instructors on site.

Cummins' "A World in Motion" Program History & Features

The development of the AWIM program was kickstarted in late-2017/early-2018 at Girls Inc. through a $11,000 Community Involvement grant awarded by the Cummins Foundation, an entity of Cummins Inc.'s Corporate Responsibility division responsible for funding projects and endeavors focused on community involvement activities organized by Cummins employees in partnership with non-profit organizations in the communities served by Cummins business units. This grant money was used to purchase AWIM project/challenge kits for 2 years for Girls Inc. and cover expenses for SAE staff to train Cummins employees and Girls Inc. Franklin program staff on leading these challenges.

The structure of the sessions is as follows:

1. Students are split into 3 larger subgroups according to their grade levels: Kindergarten to 1st grade, 2nd grade, and 3rd & 4th grade. This split was proposed by Girls Inc. staff to allow a more even division of girls within each group.

2. The 1st 10 minutes of each session involves the Cummins employees providing an overview of the activity and concepts to be covered to the entire group of 60 to 70 students across all age groups. This time is used to recap the previous session's concepts and continue off from where we left off.

3. For the next 40 to 45 minutes, the students move into their respective grade groups. Here the instructors (Cummins employees) describe in detail the activity for the session and provide detailed instructions on the tasks that have to be accomplished. Students are further broken up into their individual project teams, and each team is given the AWIM kit pertaining to the challenge/module that is being taught:
    a. Within each project team, students roleplay as different types of engineers (project engineer, test engineer, design engineer, etc.) with clearly defined roles: the design engineer uses rulers and other measuring instruments to make measurements and make component modifications, while the test engineer helps with the building of the prototype and evaluating its performance. The project engineer acts as the scribe and fills out the tables in the worksheets to record and analyze data. The roles do not stay the same from week to week but get switched among the students within the group to allow students to gain exposure to different types of engineering roles at an age-appropriate level.
    b. At this stage of the session, the volunteers move around the room to work individually with each team to see how they are faring with the tasks, and then help them out if they are struggling. The Girls Inc. staff provide invaluable assistance in coordinating the logistics by ensuring adequate supplies of materials and stationery

for each group, as well as keeping an eye out of the utilization of the challenge kits themselves.

4. In the last 5 to 10 minutes, all age groups reconvene, and the volunteers re-emphasize the concepts that were covered for that session before adjourning.

Each semester, two challenges are covered over a period of 10 to 12 weeks, thereby requiring 5 to 6 weeks per challenge. Some of the challenges/activities that have been covered as part of this program are the Gravity Cruiser Challenge [12], Making Music Challenge [13], Engineering Inspired by Nature Challenge [14], Pinball Challenge [15], Jet Toy Challenge [16] and Fuel Cell Car Challenge [17]. Figure 1 shows some of the fully built/completed prototypes from the Skimmer Challenge and Fuel Cell Car Challenge as examples of what the finished projects/challenges look like.

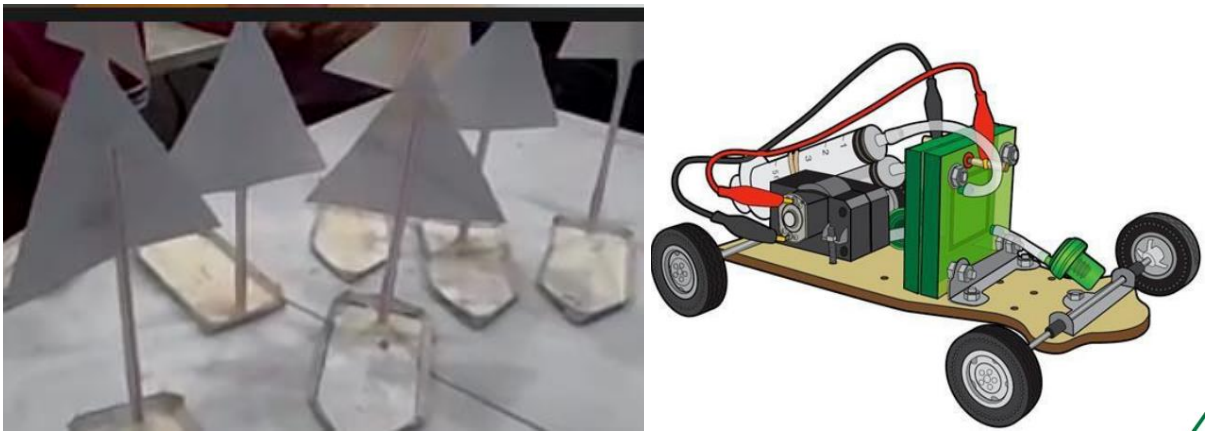

Figure 1 – (Left): Completed Skimmers from the Skimmer Challenge, and (Right): Schematic of a completed Fuel Cell Car from the Fuel Cell Challenge (Taken from:[17])

Because we are covering what was designed by SAE to be a 11 to 12 session lesson plan with three sessions per week only 1 hour per week, we have had to combine certain lessons for a particular week. Figure 2 shows a typical lesson plan for the Jet Toy Challenge. For our purposes, these 11 sessions were spread out over 5 weeks, which meant that we had to combine Lessons 1, 2 and 3 for example into 1 week. In most cases, we were able to combine lessons without skipping through some content, but we were not able to do so for all challenges. This will be a future area of research to evaluate which concepts are most critical for the Kindergarten to 4th grade groups when abridging the program.

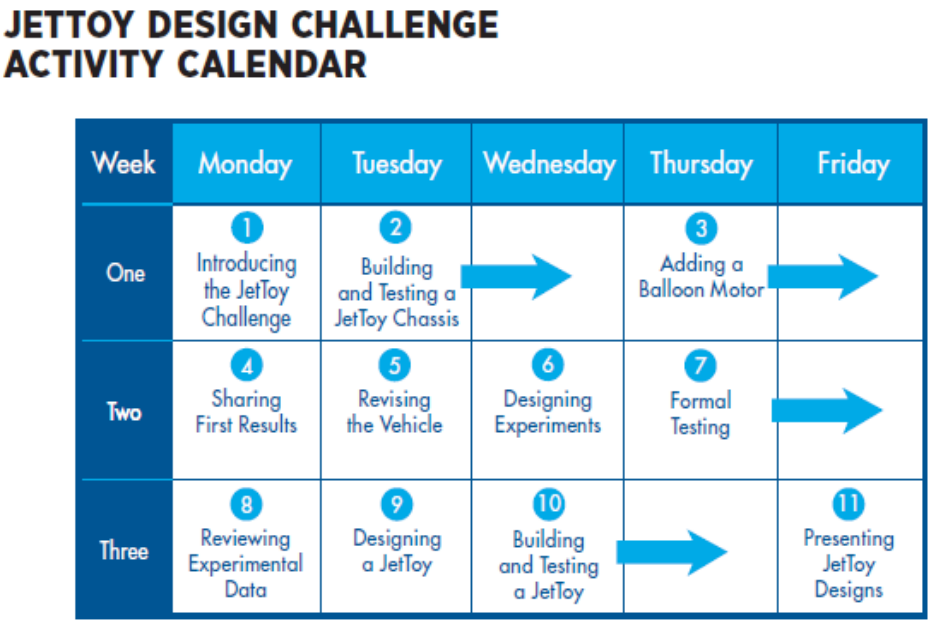

Figure 2 – Jet Toy Challenge Activity Calendar. Taken from [16]

Initial difficulties were faced in the recruitment of Cummins employees as volunteers to facilitate the lessons due to the after-school program being scheduled in the middle of the workday, which made it rather unattractive for Cummins employees to sign up for slots as they would have to leave work early to attend these sessions in Franklin. Another obstacle we faced was the content delivery structure itself; the AWIM program was originally supposed to be taught by the Girls Inc. staff, with Cummins employees serving as mentors or facilitators to assist the Girls Inc. staff and the students with tasks. It was discovered early on that due to the lack of adequate exposure of the Girls Inc. staff to STEM topics, the critical Science and Mathematics concepts were not properly emphasized during each lesson.

To address these aforementioned challenges, the following measures were taken:

i. Moving the start time of the after-school activity by half an hour from 3 pm to 3:30 pm, which made it more palatable for more Cummins employees to leave work, as it was closer to the end of the day.

ii. Heavy promotion of the AWIM curriculum opportunity through multiple avenues at Cummins, namely the Cummins Powers Women official communication channels, the various Community Involvement Teams throughout Southern Indiana, reaching out to members of Cummins' Executive Leadership Team to get their help in advertising this opportunity to their extended teams, etc.

iii. Overhauling the structure of the program such that Cummins employees are primarily responsible for lesson planning and teaching of concepts, while the Girls Inc. staff serve as facilitators instead. Content delivery approach was switched to this structure as it

was determined that Cummins employees, especially the engineers, scientists, and accounting professionals, who have a strong background in STEM fields, are well-equipped to not just instruct students in the activities, but also relate the tasks back to the appropriate Science and Engineering concepts to facilitate concept retention.

As a result of implementing these changes, the average number of volunteers per week increased from 3 to 4 per session in the Winter of 2019 to 13 to 14 per session in the Winter of 2020 just before the pandemic started. Volunteer engagement as well as concept retention by the students also seemed to have improved; however, more formal research methods need to be, and will be employed in the future to quantify the volunteer engagement and evaluate the effectiveness of this program.

The program came to a pause once the pandemic hit in March 2020, but we resumed the lessons again over Zoom in Fall of 2020 due to work from home restrictions at Cummins that prevented employees from volunteering on-site at Franklin. This time, we faced a new challenge: internet bandwidth issues that prevented connecting more laptops to the Zoom calls to allow for more than two breakout rooms, one for each set of grades (k-2 & 3rd to 4th). Because of this, we ended up getting too many volunteers from the Cummins' side per breakout room, making it difficult for every volunteer to meaningfully contribute. With only one breakout room per age group, we were not able to provide individualized attention to individual project teams over Zoom, and thus, inevitably some volunteers end up speaking more than others during the sessions. Hence, starting in Fall 2021, we had to limit the number of volunteers to 3 or 4 per breakout room, that is, 8 per session so that each volunteer could meaningfully contribute and participate effectively for the session.

Despite the challenges posed by the virtual delivery format, we were able to quickly adapt based on feedback provided by the volunteers and Girls Inc. staff to keep tweaking on the content delivery and were able to finally develop a set of best practices to administer the sessions over Zoom moving forward. Moreover, the screen sharing and other technological features of Zoom also allowed the volunteers to expose the students to spreadsheet software such as Microsoft Excel; volunteers were able to improvise by using Excel to record and plot data from each team, demonstrating to the students the importance of tables and graphs in recording & visualizing scientific and engineering data.

Proposed Plan to Evaluate Program Effectiveness

In order to further enhance this STEM outreach program and ensure that it meets the objectives of Girls Inc.'s mission to "Empower Young Women in STEM", it will be necessary to develop and utilize assessment tools to determine program effectiveness and identify shortfalls for future curriculum improvement. For K-12 STEM outreach programs such as this one, assessments such as proficiency tests are not effective in gleaning information about effectiveness, because the objective of such outreach programs is to inculcate a positive attitude and build confidence in participants about continuing their education in STEM disciplines, i.e. affective measures [18, 19]. To evaluate the impact of affective measures, pre- and post-program surveys of participants would be more appropriate to gauge the improvements that students have made. An example of such a

survey would be the Friday Institute's S-STEM surveys [20, 21]. In addition to surveying students, we also plan to conduct surveys of the Cummins employees who volunteer for this program to identify ways to make the volunteer experience more meaningful for them, and to develop solutions and/or accommodations that will help them in delivering the lessons during the sessions. We also plan to survey the staff at Girls Inc. to determine gaps in logistics support and identify solutions to the roadblocks faced on the logistics side.

At the time of writing of this WIP paper, discussions are currently under way with our community partner Girls Inc. and the Cummins' Corporate Responsibility division on what would be the most efficient way to survey the volunteers and Girls Inc. staff. In addition, we are also planning to have discussions with Engineering Education faculty from universities in the vicinity to gain advice on survey techniques and the protocols for obtaining Institutional Review Board (IRB) approvals before drafting the student surveys. Once the way forward has been established, we will look into drafting the surveys and approaching an IRB to determine the feasibility of this research. The long-term plans involve using the survey results to determine the effectiveness of the AWIM kits quantitatively, as well as look into whether we need to expand the curriculum offering beyond what AWIM can provide to include modules such as robotics. This will be an ongoing project that could span multiple years and will be a continuous process to keep enhancing the program.

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