STEM Applications: Integrating Informal Learning with the Formal Learning Environment

Abstract

Many times only a select group of students are able to participate in after school activities due to various reasons. Because only a few students are able to participate from a given class, only those students receive benefits from the extracurricular activity. Additionally, since the activity is usually informal, the students may only identify the activity as extracurricular and not make connections between the activity, their schoolwork, and real world applications. By incorporating after school activities with content in the classroom, deeper connections can be made as well as impacting a larger demographic of students. Thus, integrating informal learning with formal learning serves the dual purpose of reaching more students as well as providing a vehicle for interactive learning activities in the formal setting. This paper provides a framework for interweaving regional informal learning activities with a sequence of elective courses in science, technology, engineering, and mathematics (STEM) applications.

The framework described in this paper is specific to integrating the informal activity of a regional robotics competition (designed for 4th-12th grades) with formal learning, specifically for middle school grades (6th–8th). The STEM applications courses are designed to increase learning and develop better understanding of fundamental topics while providing preparation time for the regional robotics competition. While students are learning through the use of a robotics platform, the fundamental STEM topics for the class are re-emphasized. Having interactive projects in the classroom provides a context for the fundamental content being taught while also impacting those students who otherwise would not have been able to participate in the robotics competition. Moreover, all students in the class can be exposed to the robotics platform at some level. Additionally, since preparation for the competition is conducted through the course, more students have the opportunity to participate on the actual day of competition. This paper will provide details of the framework – that integrates informal learning with formal learning – providing examples of how this framework has been implemented and where it has been successful.

Introduction

Currently, there are many robotics-themed programs conducted in informal leaning environments[1, 2, 3, 4, 5]. These programs yield a great deal of merit by providing students, who are able to participate, with meaningful STEM experiences. In one study evaluating the impact of the FIRST®[1] program, researchers found students had a quality experience that built teamwork and communication skills while students also developed problem solving and time management techniques[6]. Additionally in the study, researchers saw an increase in students participating in the FIRST® program who went on to pursue college degrees in a science or engineering field, with many of them indicating an interest in pursuing higher level degrees of Masters and Doctorates[6]. These students also showed an aptitude for community involvement and improvement[6]. Informal learning programs show students use robotics not only for the engagement but also to provide a context for the STEM content[7].

In a paper evaluating the benefit of robotics in education, the authors acknowledged that students benefit from the innate interdisciplinary nature of robotics[8]. The authors also indicate that robotics lends itself to engaged learning at an earlier age, where students exposed to robotics show a greater achievement in the classroom[8]. Thus, the earlier the age, the more benefit received.

One can infer that students who participate in the informal robotics programs receive great benefit for their current and future academic and professional careers. However, students who are unable to participate in the informal programs are not able to reap the benefits of these programs. Various obstacles can prevent students from being able to participate in the informal program; reasons not to participate can range from logistical, time, or financial burdens. These particular reasons do reflect a lack of interest in the activity; students may have the desire to join, but for one reason or another, they are unable to stay after school and participate. By integrating the informal activity with the formal classroom environment, these otherwise unreached students can benefit from the program. Not only are these students able to participate in the activity, but because the time restraint is not as demanding, the students may be able to compete in the culminating event of the informal program since that requires only one additional day of commitment rather than multiple days.

Additionally, since informal activities are outside of the classroom, some students may only identify the activity as extracurricular and not make connections between the activity, their schoolwork, and real world applications. By incorporating after school activities with content in the classroom, deeper connections potentially can be made. Thus, integrating informal learning with formal learning serves the dual purpose of reaching more students as well as providing a vehicle for interactive learning activities in the formal setting.

Background

Initially, to combat the financial burden associated with many current informal robotics competitions, an area middle school and high school developed a small robotics competition for schools to participate. The competitions were designed for three divisions: elementary, middle, and high school. Educators in the region volunteered to design and implement the competitions.

Realizing the program had great potential for expansion, the Cyber Innovation Center (CIC), a 501c3 not-for-profit, became a sponsor and, eventually, the organizer of the event, which was given the name Regional Autonomous Robotics Circuit (RARC). Through the CIC expanding RARC, a larger population of students in the region was able to participate in the competitions.

While the expansion of the event allowed for more schools to participate, the preparation for the majority of schools was conducted outside of the classroom limiting the number of students participating. Those students who wanted to participate but were unable to stay after school could not participate in the competition. To address this issue, a middle school STEM elective curriculum was developed with open weeks to allow for event preparation. Initially, the curriculum was called STEM Applications I, II, and III. It is currently being redesigned using a slightly different approach and will be retitled STEM Explore, Discover, and Apply. This curriculum allows for the seamless integration of the RARC competitions with the formal learning environment. More students are able to participate in the RARC events as well and receive a valuable STEM experience through the other topics covered in the elective course. Additionally, incorporating the informal learning activity in the formal learning environment over a three to four week module, allows the teachers more time to delve into the technology and fundamental principles associated with the informal competition.

Informal Learning - RARC Layout

RARC consists of four Saturday competitions throughout the school year with three divisions: elementary, middle, and high school. During each competition, the divisions have one to three STEM challenges that utilize a robotics platform. The challenges are designed to be robotic platform independent. Schools can use any platform they have available to them such as Parallax Boe-Bot®, Lego® Mindstorms® NXT, VEX®.

In addition to the STEM challenges, the teams in each division are expected to compete in a liberal arts challenge. In the past, students have had to build poster boards to display research on a topic, create videos on a "how to" with the robot, conduct presentations in front of a panel of judges, as well as other liberal arts themed projects. The competition designers felt including the liberal arts with the STEM shows the students context for the STEM topics; thus, broadening the experience of the participants beyond the typical robotics portion of competitions.

The competitions held during the school year build on one another, but schools are not required to participate in every event. If a school is not able to assemble a team before the first competition, they can still sign up for the next competition later in the year. Scores from previous competitions are cumulative and are used to name the division grand champion.

Approximately four to six weeks prior to the competition, teams are supplied with challenge guidelines. The guidelines reveal to the teams the challenges they are expected to have their robotics platform perform. For example, one challenge might be to follow a dark line using a sensor. Students will have to figure out that they need a photoresistor to make the robot follow the dark line. All the programming and preparation is the teams' responsibility. In addition to the information about the STEM challenges, teams receive instructions for the liberal arts challenges. Teams are expected to multi-task by preparing for both the STEM and liberal arts challenges in the weeks prior to the competition.

For the first three competitions, the teams know specific tasks their robots have to complete. The final competition, however, is open-ended. In the challenge guidelines released prior to the competition, teams are given a list of various functions they should be prepared to have their robots perform. This adds a degree of uncertainty and requires the students to understand their robotics platform as well as be prepared for whatever task is set before them.

Formal Learning - Curriculum Layout

A qualified teacher in the region was tasked with creating STEM Applications I, II, & III (STEM Apps), a three part course that could be integrated in the middle schools as an elective for 6^{th}, 7^{th}, and 8^{th} grades. The initial design of the course centered on the RARC competitions and STEM topics. Each level of the course begins with learning the basics of the robotics platform for the first few weeks. The method of learning the platform is left to the discretion of the teacher with suggested activities provided by the STEM Apps designer.

After the first few weeks the students have a good understanding of the robotics platform. They, then, transition into a unit on a STEM topic. The STEM Apps courses have suggested STEM units for each grade level to fill the content for these weeks. The STEM units leverage the online curricula at educate.intel.com, which is part of the Intel ® Company's educational outreach initiatives[9]. Following the STEM unit and approximately four weeks prior to the first RARC competition, the curriculum shifts to a RARC unit geared towards the task of the upcoming competition. Students will work on completing the liberal arts task as well as prepare for the STEM challenges. Following the RARC competition, the STEM Apps curriculum transitions to another STEM unit; the course follows this pattern throughout the year.

In an effort to make the curriculum more robust, the STEM Apps course is undergoing a redesign. Instead of STEM Applications I, II, & III, the course will be called STEM Explore, Discover, and Apply (STEM EDA) to reflect the various level of STEM development in the middle school students. Students will explore (6th grade), discover (7th grade), and apply (8th grade) STEM fundamental topics throughout the course.

The online content in STEM Apps is a useful resource to the teachers, but does lack a sense of continuity. A team of curriculum design specialists are redesigning the content. Instead of using the online content in STEM Apps, the design team will exploit "classic" science projects (e.g., the egg drop, volcano, catapult, bottle rockets). STEM EDA will maintain the modular approach that STEM Apps utilized. However, to provide continuity, depth, and meaning, the curriculum will leverage the engineering design process. Additionally, much like the RARC competitions, context will be given to each of the projects through the use of liberal arts. This three week approach to a project that would typically elapse approximately three days allows for robustness and opportunity to address many STEM and liberal arts topics. Design projects will be used to "lead the students intellectually," rather than just provide a fun and engaging activity, an attribute of a positive design experience as described by Wiggins and McTighe[10].

For example, the activity in the first module of the course will be the classic "create a vessel that holds an egg and aids its survival of a fall from a specified height." There are numerous STEM fundamentals that can be taken from this project; however, many times when the project is done, the fundamentals are over looked and the activity takes the main focus. Students typically spend a day or two building a vessel, drop the vessel hoping that the egg will not break, and then they are done. Since the egg drop is the first module in STEM EDA, the project will serve many purposes. In addition to the illustrating the fundamental physical science concepts associated with the egg drop, the project will serve as the vehicle used to frame the importance of the engineering design process. The first day students will receive a list of random items allowed for the vessel design. They will only have the first class period to build the vessel. The next class students will drop the vessel with an egg from a specified height and see if it survives (much like how the project is usually conducted). Many students will fail the task due to the limited time spent designing and building their vessels. The following class will introduce the engineering design process. Students will identify the steps of the engineering design process they did not perform. Students will then begin a redesign of their vessel by including elements of research and more time brainstorming, deciding on the solutions, and building the prototype. Within the research portion of the class, students will learn about STEM fundamentals (e.g., gravity, force, acceleration, velocity, kinetic energy, potential energy, air resistance) associated with the egg drop and how their vessel design is impacted by the fundamentals.

In addition to the engineering design process and the STEM fundamentals, students will be given a context for the egg drop. In STEM Apply, for instance, the context will be, "the government is dropping food supplies out of a plane to refugees in a foreign country." Students will have to research the country and learn about its environment and culture. Additionally, in STEM Apply, there will be no restrictions on the vessel size or amount of materials the students can use to build their vessels. However, prices will be associated with the various materials, and students will have to keep economics in mind when choosing the materials for their vessel. Therefore, this module and subsequent modules allow for a multi-dimensional approach to projects that are generally seen as one-dimensional.

After completing the build of their vessels for the second time, students will test their new design. Because the students will have spent more time understanding the problem, researching, brainstorming, and building the prototype, the vessels should perform better than their first attempt at the egg drop. This process will build an appreciation for the engineering design process, instill a culture of teamwork, communication, and problem-solving in the students early in the course as well as develop their understanding of STEM fundamentals associated with the project. Also, students will gain an understanding of the engineering design process that will carry through to the subsequent modules of the course. This elective curriculum will provide a method for integrating engineering with K-12 education through the use of the engineering design process which satisfies the current national initiative to incorporate engineering in the classroom[11]. As the year progress, with each module emphasizing the importance of the engineering design process, the student will develop an appreciation and inclination for the process.

Each module in STEM EDA will last approximately –three to four weeks; therefore, 12 modules will be created for each level of the curriculum (Explore, Discover, & Apply). Schools will have the ability to be flexible with the implementation of the course. The ideal environment for the curriculum is a year-long elective course. Enough content in each course (Explore, Discover, & Apply) will be developed to fill a year's worth of material without the insertion of the informal learning activities. However, because of the modular design teachers will be able to insert a RARC module similar to the current design of the STEM Apps course. This also allows teachers the freedom to insert other informal learning activities into the formal learning environment as they see fit.

The STEM EDA curriculum is under development and will be piloted in the upcoming 2013-2014 school year. Schools participating in RARC as well as schools not participating in RARC will pilot the curriculum.

Framework

In order to integrate the informal learning activity with the formal learning environment a framework has been developed. The specifics included in the framework are applicable to RARC and STEM EDA curriculum. However, it is the opinion of the authors that the framework itself could stand alone and be used for other informal learning activities and formal curricula. The framework is designed for a year-long middle school schedule, where class periods last approximately 55 minutes.

Table 1 shows the weekly breakdown of a STEM elective course. Notice the first module column does not contain any informal activity modules. The second module column replaces four of the STEM modules with RARC activities. These informal activities that are now in the formal setting are distinguished by red text. The modules in red can be interchanged with other modules. For instance, RARC Module 1 does not have to replace the Bottle Rockets lesson. A teacher can decide to adjust the schedule and teach the Bottle Rockets lesson in place of the Earthquakes lesson.

Table 1. The framework for integrating informal activities into the formal classroom atmosphere.

Weeks	Modules (Without RARC)	Modules (With RARC)
Week 1 – 3	STEM Module 1 – Engineering Design Process (Egg Drop)	STEM Module 1 – Engineering Design Process (Egg Drop)
Week 4 – 6	STEM Module 2 – Bottle Rockets	RARC Module 1
Week 7 – 9	STEM Module 3 – Electricity	STEM Module 3 – Electricity
Week 10 – 12	STEM Module 4 –Catapult	STEM Module 4 –Catapult
Week 13 – 15	STEM Module 5 – Boats	RARC Module 2
Week 16 – 18	STEM Module 6 – Trusses	STEM Module 6 – Trusses
Week 19 – 21	STEM Module 7 – Roller Coasters	STEM Module 7 – Roller Coasters
Week 22 – 24	STEM Module 8 – Volcano	RARC Module 3
Week 25 – 27	STEM Module 9 – Earthquakes	STEM Module 9 – Earthquakes
Week 28 – 30	STEM Module 10 – Solar Oven	STEM Module 10 – Solar Oven
Week 31 – 33	STEM Module 11 – Music	RARC Activity 4
Week 34 – 36	STEM Module 12 – Race cars	STEM Module 12 – Race cars

Because each module uses the engineering design process, students will obtain a good basis for design which can also transfer into the informal activity modules. Additionally, since each STEM module drives to STEM fundamental topics, students will be to relate these principles to the informal activity modules and vice versa.

Framework in Practice

Currently, all seven middle schools within a school district in the RARC region are implementing the STEM Apps curriculum. At the most recent RARC competition, there were a total of 139 teams from 43 participating schools. Each team consists of 2–6 students. Table 2 shows the growth of the event from Competition 1 to Competition 2 during the 2012–2013 circuit.

Table 2. 2012 – 2013 RARC Competition Participants

	Competition 1	Competition 2
Schools	39	43
Teams	125	139
Districts	5	6

Looking specifically at Competition 2, out of the 139 teams 69 of those were from middle schools. There were 14 middle schools participating in the event. Half of those schools are implementing the STEM Apps curriculum. The STEM Apps schools accounted for 68% of the middle school teams. Table 3 outlines the number of teams sent form the various middle schools. Note the STEM Apps middle schools are emphasized using red font. The schools sending more teams tend to come from the STEM Apps schools with the exception of two non-STEM Apps schools.

Table 3. Number of middle school teams sent by each middle school.

Middle School	Number of Teams
STEM Apps School A	15
STEM Apps School B	11
Non-STEM Apps School	10
STEM Apps School C	7
STEM Apps School D	6
Non-STEM Apps School	5
STEM Apps School E	4
STEM Apps School F	2
Non-STEM Apps School	2
STEM Apps School G	2
Non-STEM Apps School	2
Non-STEM Apps School	1
Non-STEM Apps School	1
Non-STEM Apps School	1

Table 4 outlines the participants demographically by ethnicity for the 2012–2013 circuit. Approximately 26% of participants are from underrepresented groups.

Table 4. Ethnic demographic makeup of RARC participants.

	Elementary School	Middle School	High School
African American	3	34	13
Asian/Pacific Islander	2	5	2
Hispanic	13	7	1
Native American/Alaskan	2	0	0
White	128	185	53
Multi	14	8	4

Research has shown a lack of women pursing degrees in science and engineering[12, 13, 14]. However, participation in STEM activities early in their academic career can influence females to maintain interest in STEM[12, 13, 15]. In that respect, RARC has seen a positive trend that reveals an increase in the number of female participants in RARC from the 2011–2012 and 2012–2013 seasons. Table 5 outlines the trend from RARC seasons 2011–2012 and 2012–2013. Note that the number of females participating in RARC from 2011-2012 increased from 16% to 25%.

Table 5. Gender demographic outline from 2011–2012 to 2012–2013 RARC events.

	RARC 2011-2012				RARC 2012-2013	
	No. Participants	Percentage			No. Participants	Percentage
Boys	426	84%		Boys	533	75%
Girls	82	16%		Girls	179	25%

Conclusion

It is too early in the implementation of RARC competitions with the STEM Apps/STEM EDA development to conclude with certainty that integrating the informal activity into the formal classroom atmosphere increases the involvement in RARC competitions or increases involvement by underrepresented groups – both ethnic and gender. However, knowing entire classes participate in RARC activities during the school day as opposed to only those who can stay after school, one can infer that more students are exposed to the components of the informal activity and, therefore, reap the benefits of the program. Including the informal learning program with the formal learning atmosphere reduces any form of bias towards underrepresented populations and, thus, potentially increases the likelihood of those populations participating in the actual RARC competitions. Research has shown that growing the number of underrepresented populations in science and engineering programs is essential to the progression of these fields[16]. By creating more opportunities while students are young and impressionable, steps are taken in the right direction towards growing the interest of these populations in engineering and science.

The initiative to increasing the number of women in science and engineering is well known. Specifically, a paper on increasing recruitment and retention of women in STEM, the authors report that the females' positive attitude towards STEM changes by middle school[17]. By maintaining engaging STEM activities in the middle school grades, that attitude shift might be stunted. Thus, integrating the informal STEM learning activities into the formal learning environment could provide female students the opportunity to stay engaged in STEM rather than develop the attitude shift that results in a disengagement of STEM subjects.

Through partnerships with NICERC and the schools implementing the STEM elective curriculum, opportunities to address research questions are available. The success of the program can be assessed, which can be addressed by looking at enrollment and demographics, but also through student engagement and attitudes towards the course. Additionally, we have already seen a correlation for increase in enrollment at the RARC with those schools implementing STEM Apps. As the elective course progresses to more schools, we can collect data to see how integrating the informal learning environment with the formal learning environment affects the student attitudes towards STEM. Additionally, how the students implement the engineering design process learned through the modules, with the design associated with the informal activity can be assessed. Moreover, through the partnership with the schools, more research can be conducted with gender views towards STEM and liberal arts projects. Same gender teams and mixed gender teams can be established and assessed. Creating the framework for a course that allows for the integration of informal and formal learning environments opens the door for a variety of research avenues.

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