Abstract – Science Technology Engineering and Mathematics UPRM K-12 Partnership Circles (STEM Circles) is a proposal for an after school program developed by the University of Puerto Rico Mayagüez Campus (UPRM) and submitted to the National Science Foundation. The purpose of the STEM Circles is to create collaboration between the UPRM and the Puerto Rico Department of Education (DE) to develop an organization that both persuades students to learn and do more science and mathematics and provides teachers with support to coach the students in this endeavor. The STEM Circles will be associated with the schools and incorporate exciting science activities and promote and facilitate student participation in competitive events (math and science fairs, math Olympics, among others) within a structure that provide support, recognition, and near term goals. During the academic year the UPRM faculty participants will train the teachers in problem solving techniques, inquiry-project based learning, how to make a presentation, and classroom assessment techniques, among others. In addition, the teachers and students will participate in workshops applying mathematics, science, and technology concepts. The workshops will be designed to provide participants better understanding about the concept of working in teams, making hard decisions, following ethical procedures, and solving problems. During these workshop activities, the participants will have the opportunity to interact with university faculty, laboratory technicians, mathematicians, scientists, engineers, and undergraduate and graduate students selected to share their experiences. A major component of STEM Circles will be creativity and design competition. Assessment of this program will play an important role to determining where the program is successful and how it impacts the participants. This paper presents the proposed program and its proposed assessment.

Index Terms – K-12 programs, STEM, teamwork competition

INTRODUCTION

The STEM Circles (Science Technology Engineering and Mathematics UPRM K-12 Partnership Circles) is a proposal for an after school program developed by the University of Puerto Rico Mayagüez Campus (UPRM) and submitted for sponsor to the National Science Foundation (NSF). The purpose of the STEM Circles is to create collaboration between the UPRM and the Puerto Rico Department of Education (DE) to develop an organization that both persuades students to learn and do more science and mathematics and provides teachers with support to coach the students in this endeavor.

JUSTIFICATION, GOAL AND OBJECTIVES

I. Justification

The problem is that pre-college students, especially those from underachieving schools, are not learning enough science and mathematics to enter and complete university programs in, science, technology, engineering, and mathematics. The extent and persistence of the problem is documented [7]. TABLE I shows the report of the Puerto Rico Department of Education on the Puerto Rican Competency Exams that were administered to over 90% of the students in the applicable grades. The table shows the tiny percentage of students from the public schools in Puerto Rico that were classified competent in Chemistry and Physics.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Year</th>
<th>Mathematics</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>1999-2000</td>
<td>34.6</td>
<td>61.6</td>
<td>7.2</td>
<td>9.9</td>
</tr>
<tr>
<td>1998-1999</td>
<td>36.7</td>
<td>61.3</td>
<td>6.2</td>
<td>12.4</td>
<td></td>
</tr>
<tr>
<td>1997-1998</td>
<td>36.8</td>
<td>64.4</td>
<td>6.1</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>1996-1997</td>
<td>41.5</td>
<td>73.1</td>
<td>6.3</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1999-2000</td>
<td>43.2</td>
<td>33.2</td>
<td></td>
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</tr>
<tr>
<td>1998-1999</td>
<td>44.4</td>
<td>34.0</td>
<td></td>
<td></td>
<td></td>
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<td>1997-1998</td>
<td>41.5</td>
<td>31.5</td>
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<td></td>
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</tr>
<tr>
<td>1996-1997</td>
<td>41.1</td>
<td>32.1</td>
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</tr>
</tbody>
</table>
TABLE I does not show the low level of mathematical achievement that is classified as competent. However, Dr. Ramirez and Dr. Wayland developed and administered a Third International Mathematics and Science Study (TIMSS) style assessment to measure academic performances in mathematics and to correlate that performance with various environmental factors. Students from fourth, eighth, and twelfth grades of public schools in the Western Region of Puerto Rico were given tests with multiple choice items similar to those utilized by TIMSS. The average score for the eighth grade was just under 25%. Since each item offered five choices, the average was slightly better than the score to be expected from random markings. The average score for the twelfth grade was 29.2%. The one bright spot in the assessment was the positive effect (5% increases) of math and/or science clubs on average test scores for a school.

The experience across the United States is quite similar to that in Puerto Rico. During the past decade, the National Assessment of Educational Progress (NAEP) and the Scholastic Aptitude Test (SAT) scores in mathematics and science have risen slightly, while the ACT college entrance exam scores have remained flat. Based on NAEP and TIMSS achievement tests and other evidence, the Glenn Commission [3] concluded that grades K-12 have made little or no progress in the levels of achievement in mathematics and science over 11 years.

Around 1995 there was a marked decrease of funds for projects that work directly with students and a sharp increase in funds for teacher enhancement projects. Improving teacher preparation and providing teachers with better support is important for many reasons. However, it is becoming apparent that more work by better prepared teachers does not automatically lead to better academic performance by students. After nine years of focusing on improving science and mathematics teachers, curricula, and materials (and there is no doubt that there have been significant improvements), it seems like time to ask why aren't students doing better?

Persuading students to study more is an uphill battle. In nowadays society, teenagers are expected to be in a rebellious “us against them” stage of their lives. There is enormous peer pressure to not over-achieve, to have fun, and to reject the impositions of school and parental authority. Today social action students work consciously and unconsciously together to limit their curricula and their study requirements. There are so many distractions: friends, MTV, cars, computers, sports, hanging out, the opposite sex. Not only are there distractions, but the popular culture downplays the importance of academic preparation. Being “dumb” is cool. Studying is for nerds.

If the problem is attitudes and habits, then the solution must focus on motivation and persuasion. This project proposes the development of a mechanism to provide students a way to learn and do more science, technology, engineering, and mathematics by the exposition to exciting science activities and the participation in competitive events. The STEM Circles will serve as a point of collaboration between the school teachers, graduate and undergraduate students, and pre-college students to have fun doing science, technology, engineering, and mathematics. This collaboration will provide a solid platform to motivate and prepare students to pursue careers in science, technology, engineering, and mathematics disciplines.

II. Goal and Objectives

The goal of the STEM Circles is to create collaboration between the UPRM and DE to develop an organization that both persuades students to learn and do more science and mathematics and provide teachers with knowledgeable support to coach the students in this endeavor [2]. This goal will be achieved through the following main objectives:

a) develop a mechanism to increase the number of students from middle and high schools in the Western Region of Puerto Rico who are prepared to succeed in university programs in science, technology, engineering and mathematics; and

b) provide professional development activities to school teachers.

The focus of the project is the development and support of after school Science Technology Engineering and Mathematics UPRM K-12 Partnership Circles (STEM Circles) [2].

STRATEGY

The STEM Circles will be associated with the schools and will incorporate exciting science activities and promote and facilitate student participation in competitive events (math and science fairs, Math Counts, Math Olympics, among others) within a structure that provides support, recognition, and near term goals. The STEM Circles themselves will serve as a point of contact between the student and the fun of doing science, mathematics, and engineering. The organization of STEM Circles will build a systematic program of achievable objectives that students can follow to success in mathematics, science, and technology [6]. Each Circle will have a leadership team composed of two mathematics/science teachers, and two either graduate or undergraduate students (GUS). The STEM Circles will have a minimum of six active members; and meet two days per week for two and a half hours after school on school premises. Discussions with local teachers indicate that operation on school premises two days per week immediately after school hours provides students their best opportunity to participate while minimizing transportation complications and costs.

There will be a cumulative competition between Circles for recognition and rewards. The structure of the competition will respond dynamically to the quantity and quality of the science and mathematics achievements [1]. Circle leaders will receive an initial point distribution for the competition that includes:

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Circle leaders will prepare weekly reports regarding achievements with respect to the competition. Project staff will prepare and distribute weekly standings among competitors from the reports. Once a month, recognition with modest prizes, such as, books, calculators, or creative games will be awarded to Circles and individual members. These monthly awards will be primarily for reaching modest program goals. Some recognition will be given to monthly leaders. One or two prizes will be awarded with a random element just to reinforce the basic value of participation. Once a month, Circle leaders will have the opportunity to propose and approve changes in the recognition and point distribution scheme that can be applied to subsequent months. Changes will be approved by a simple majority of Circle leaders subject to approval by the project director. At the end of the year, various prizes will be awarded to the Circles and individual members based on the total cumulative points for the year. The grand prize for the high school Circle with the greatest total cumulative point will include a tour to the Kennedy Space Center and computer kits for five members of the Circle. The members will be accompanied to Kennedy Space Center by their leaders and the project director. The grand prize for the intermediate school Circle with the greatest total cumulative points will be computer kits for three members. Two additional computer kits will be awarded to individual Circle members in a performance-biased raffle.

In summary, the project will sponsor STEM Circles in six public high schools and six public intermediate schools in Western Puerto Rico for one year. The project will:

- train leaders to organize STEM Circles in their schools;
- prepare leaders to conduct activities from NASA programs such as GLOBE;
- provide leaders with the information and the background science needed to utilize NASA developed materials such as Black Holes;
- provide STEM Circles with the materials and information needed to participate in local, regional, and national mathematics, science, and technology competitions;
- support leaders with small stipends and educational materials;
- host a mini-conference for the Circles to present their best work of the year;
- conduct a year long competition among STEM Circles; and
- develop a systematic program of achievable objectives for STEM Circle members.

Selection Procedure

All of the public intermediate and high schools in the Western Region will be invited to submit a proposal to host a STEM Circle. The selection of schools to host STEM Circles will be made by the project director on a competitive basis. The selection of host schools will take into consideration:

- the experience of the leadership team proposed,
- the facilities offered for use by the STEM Circle,
- the number and percentage of students expected to participate,
- the socio-economic profile of the school, and
- the history of school support for student participation in mathematics and science.

Partnership Plan

UPRM is a principal contributor in the Puerto Rican government's plan to develop a new Techno-Economic Corridor in Western Puerto Rico. As such, UPRM is strongly committed to developing a large pool of highly qualified scientists and engineers to support the research and development efforts of Puerto Rico's new focus for economic development represented by the Techno-Economic Corridor. The potential economic importance of the new Techno-Economic Corridor increases the longstanding interest of UPRM in increasing the number of high school graduates who are prepared to pursue academic programs in engineering, science, and mathematics.

UPRM is actively pursuing ways to increase the teaching effectiveness of its faculty and the learning proficiency of its students. The principal task of the campus professional development office is to improve the teaching effectiveness of UPRM faculty and to enhance the preparation of the future teachers in UPRM academic programs. UPRM also participates in the PR-CETP project that specifically seeks to improve the preparation of science and mathematics teachers. UPRM is one of the partners in the project “Learning Science and Mathematics Alliance” (AlACiMa), a project sponsored by NSF Math Science Partnership Program for the professional development of in-service and pre-service teachers from the Puerto Rico Department of Education to improve the academic performance of K-12 students. The UPRM is a leader in the use of technology and active learning methods in the classroom.

UPRM supports several initiatives to promote the interest of pre-college students in engineering, science, and mathematics including a pre-engineering summer program. Each year the campus hosts competitions such as: Math Olympiads, Math Counts, FSEA, and Computer Programming competitions. Other special events for pre-college students hosted at UPRM are: regional science fairs; EXITE (Exploring Interest in Engineering and Technology), a summer camp for girls from middle schools to teach them early in life what engineering is about; ECOENAS (The Exploring Career Options in Engineering, Agricultural and Sciences Program at the University of Puerto Rico Mayagüez), a program designed to introduce high school students to different
professions in engineering, agriculture, and science field; and the Transportation Institute, a summer program designed to introduce pre-college students to transportation from the Civil Engineering perspective. The UPRM faculty responsible for organizing these events will be encouraged to collaborate with Dr. Bartolomei, Dr. Ramírez, Dr. Wayland, and the STEM Circles.

UPRM will provide the physical and academic facilities for training of STEM Circle leaders, particularly computer centers, science and engineering laboratories, and libraries. UPRM will provide the physical facilities for special STEM Circle competitions. UPRM will also grant academic release to PI/CoPIs amounting to 1/3 of their normal academic load to dedicate to the project.

The Puerto Rico Department of Education (PRDE) will encourage the participation of twenty-four teachers from twelve schools. PRDE is keenly interested in improving the achievement of students in science and mathematics. PRDE will supply essential data from previous and future Puerto Rican Competency Exams for Western Region Schools to measure the relative impact of STEM Circles and teacher orientation on student performance in science and mathematics. If initial project efforts show promise of improving student achievement in mathematics and science, PRDE will support an expansion of the project for further study.

Through the approval of this project by the National Science Foundation (NSF), UPRM and PRDE will create an organization that persuades pre-college students to develop the academic and character profiles needed to pursue careers in science, technology, engineering and mathematics. FIGURE I shows the relative responsibilities of NSF, UPRM, and the PRDE within the project.

**ACTIVITIES**

The STEM Circles will be structured around various academic activities, conferences and laboratory activities, hands-on workshops, and field trips. Some of the activities will be:

1. **Workshop: Working with the Internet**

The goal of this activity is to familiarize the participants with the basic principles and technology needed to look for information on the Internet. This workshop will present basic concepts related to World Wide Web communication. It includes the use of different search engines and exploration of some web sites related to STEM, for example: [http://education.nasa.gov](http://education.nasa.gov), [http://learn.arc.nasa.gov](http://learn.arc.nasa.gov), [http://cse.ssl.berkeley.edu](http://cse.ssl.berkeley.edu), [http://www.enc.org](http://www.enc.org), [http://school.discovery.com](http://school.discovery.com), and [http://www.nctm.org/](http://www.nctm.org/).

2. **Design your Web Page Seminar**

The purpose of this activity is to teach the participants to create their own web site and post it on the net. This seminar will help the participants understand how a web site works as well as preparing them to use the Internet. Students will be guided in the creation of their own web site. Also, they will be able to open a Free-Email Account.

3. **Problem Solving Techniques**

At the end of this activity, students will be able to make systematic use of the major steps in the engineering problem solving techniques. This seminar will focus on the creative process and how it relates to the engineering problem solving process. Participants will be introduced to the brainstorming process and will discuss the importance of analyzing information received and its value. Major emphasis will be placed on the fact that many of science and engineering’s greatest discoveries were made in unexpected ways. A key aspect of this seminar will be its attempt to tap students’ own to develop discovery and learning methodologies that work for them.

4. **Team Building Seminar**

At the end of this activity, participants will be able to identify the various team-building and consensus-reaching concepts commonly used, and to apply the concepts in real life situations. This seminar will introduce to team building concepts, as applied in a real life situation with a metaphorical comparison between the behavior of geese and team work. The workshop will include a team activity that presents the participants with the means to recognize and manage the difficulties, sacrifices, and satisfaction that come with operating in a team-conscious environment. The activity will serve as a good complement to prepare the participants to work as a team solving the problems confronted in the design of a robot.
5. **Construct your own Robot**

At the end of a series of workshops, participants will program and build a robot using LEGO® MINDSTORMSTM. This activity will include lectures to introduce participants to the basic concepts of programming a robot. During the workshops, the students will have the experience of constructing different robots with a set of LEGO®. Also, they will learn to program the RCX using LEGO® RCX Code, NQC language and other programming languages.

6. **Workshop: How to make a presentation?**

The participants will learn to prepare presentations using computers. The students will learn the effects of gestures, vocabulary, and dress during a presentation. They will learn how to use non-verbal gestures to reinforce verbal messages, audience-specific vocabulary to capture attention, and the dress to gain audience trust. This seminar will teach the participants to prepare a presentation using Power Point. One of the authentic tasks for the participants will be to develop a presentation of the objectives, the methodology, and the conclusions of their design project. The workshop will be divided in three parts: lecture and discussion of effective practices in preparing and delivering a presentation, a team discussion the design project and what to present, and finally the preparation the presentation including audiovisual material with animation.

7. **Visits to the Department of Mathematics, Biology, Physics, Chemistry**

The purpose of these visits will be to let the participants understand the types of projects and areas of research in Mathematics, Biology, Physics, Chemistry and Engineering.

8. **Design Competition**

A major aspect of the STEM Circles will be a Design Competition where the participants will have the opportunity to show their inventiveness. This activity will be created and directed by Dr. Sonia M. Bartolomei-Suárez from the Department of Industrial Engineering. The Design Competition will start with a problem description, and finish with a competition using a robot built using LEGO® MINDSTORMSTM. Participants will be organized in teams of five students per STEM Circle. Each team will choose a name and after receiving the problem description and the set of specifications, they will design and build a robot solution for the problem. Then they will compete.

At the end of the competition, various prizes will be awarded to the teams based on the total cumulative points. The best team of the competition will receive sets of LEGO® MINDSTORMSTM for its STEM Circle.

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**EVALUATION AND DISSEMINATION**

Evaluation is a critical part of the proposed project. Essentially the purpose of the project is to show that STEM Circles can provide an effective means of motivating intermediate and high school students to learn more science and mathematics. The project will impact twelve STEM Circles at six high schools and six junior high schools in Western Puerto Rico.

The following evaluation scheme will be used to determine if STEM Circles have succeeded in encouraging students from public schools of Western Puerto Rico to invest the time and effort to learn more science and mathematics. The measures of success are:

- At least 12 STEM Circles will be established with a total of more than 100 members.
- At least 10 STEM Circles will actively participate in national programs as FSEA, JETS, NASA GLOBE, among others.
- At least 10 STEM Circles will participate in two or more existing competitions, such as Math Olympiads, Math Counts, or the annual Science Bowl.
- A mathematics assessment test will be administered to students in Western Region public schools. The average performance of the top quartile of students from STEM Circles schools will be at least 5% above the average performance of the top quartile of students from non-STEM Circle schools.
- The Department of Education of Puerto Rico administers the Puerto Rican Academic Achievement Test every year. The average performance of the top quartile of students from STEM Circles Schools on the mathematics and science portions of this test will be at least 5% above the average performance of the top quartile of students from non-STEM Circle schools.
- The average performance of the top quartile of students from each STEM Circles School on the mathematics and science portions of the Puerto Rican Academic Achievement Test will increase at least 5% from the previous year.
- The proposal authors will produce a proposal to expand from 12 to 20 or more STEM Circle Schools. The proposal will include longer term measures of success.

The previous measures do not correspond to an overnight revolution. They are intended to provide a clear indication that STEM Circles can change student culture. Besides providing a proof of concept, the project is a learning opportunity. Every aspect of the project will be scrutinized and evaluated to determine what is effective, what is not effective, and what can be improved to be more effective.

Each STEM Circle leader will be evaluated by the participants. This evaluation covers the organization, the conceptual content, the design, the human resources, the materials, the presentation, the use of time, and the relevance of
the activity itself. These evaluations will allow the PI/CoPIs to make appropriate adjustments in subsequent activities for the STEM Circle Leaders. Participant evaluation of project activities also provides an opportunity for STEM Circle Leaders to learn to evaluate their own activities objectively.

Each STEM Circles activity will be evaluated by the students and by the leaders. These evaluations will address the conceptual content, the presentation, the design, and the intrinsic interest of the activity itself. These evaluations will also provide STEM Circle members the opportunity to make creative suggestions for modification or expansion of activities. PI/CoPIs and STEM Circle leaders will consider adjustments that might be appropriate for subsequent activities.

At the end of the year, an external evaluator will work with the STEM Circle leaders to evaluate the effect of the project on the STEM Circle students and on the GUS and school teachers themselves. The evaluator will submit a report to the PI that summarizes all her findings. This report will be included in the annual report submitted to NSF. The evaluator will be asked to devise additional means to assess two items:

1) the tendency of students who participated in STEM Circles to spend additional hours studying science and mathematics, and

2) the tendency of students who participated in STEM Circles to pursue studies in science, engineering, mathematics, or technology.

The PI/CoPIs will present project results in local, regional, national and international conventions such as: The American Society of Engineering in Education (ASEE), International Conference on Engineering Education (ICEE), International Conference on Engineering Education and Research (ICEER), College Entrance Examination Board Latin America Congress, among others. The GUS and school teachers will be encouraged to present experiences with STEM Circles in local conferences such as: Puerto Rican Mathematics Teachers Association (PRMTA) Conference, Junior Technical Meeting of the American Chemical Society, among others.

There is great potential for the application of results and knowledge obtained from this initiative. As mentioned before, the public schools in Puerto Rico share many problems with the inner city schools of the U.S. such as high incidence of crime and violence, serious drug problems, high dropout rates, and low average family incomes. The strategy used in this project will be made available for implementation in inner city schools. Therefore, the dissemination of knowledge and results will be carried out through the following mechanisms:

- A Web page with a description of the project, activities, and results.

- A newsletter to be distributed among the academic community in Puerto Rico and the mainland on a yearly basis throughout the duration of this research.

**CONCLUSIONS**

This paper presents an initiative called STEM Circles whose purpose is to create a collaboration between UPRM and the Puerto Rico Department of Education (PRDE) to persuade students to learn and do more science and mathematics and provide teachers with support to coach the students in this endeavor.

With the approval of this project by the National Science Foundation (NSF), UPRM and PRDE will have the opportunity to create an organization that persuades pre-college students to develop the academic and character profiles needed to pursue careers in science, technology, engineering and mathematics.

**REFERENCES**


