Regional Autonomous Robotics Circuit: Providing Informal Approaches to STEM Education

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JoAnn M. Marshall is the events coordinator for the Cyber Innovation Center. In that role, she recruits schools to participate in the Regional Autonomous Robotics Circuit (RARC), facilitates committee meetings, coordinates event logistics, and serves as a resource to participating teachers. JoAnn received her Bachelor degree from the University of Alabama and her Master degree from the University of Georgia. Her professional career has been dedicated to non-profit organizations in the form of events planning, development, grant writing, and coordinating educational activities for K-12 students.

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G.B. Cazes serves as the Cyber Innovation Center's (CIC) Vice President and Director of the CIC's National Integrated Cyber Education Research Center (NICERC). The CIC is a 501c3 not-for-profit corporation whose mission is to support the development of a knowledge-based economy throughout the region. To that end, the CIC developed NICERC to oversee its robust academic outreach and workforce development program. The mission of NICERC is to foster integrated curricular experiences across multiple disciplines in both university and K-12 environments.

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G.B. attended Centenary College and received his Bachelor degree in 2002 and his Master of Business Administration in 2011. In 2012, he became an adjunct professor at Centenary College. G.B. also serves as an advisor on multiple boards for various non-profits and educational institutions throughout the region.

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Introduction

The National Science Board, the President's Council of Advisors on Science and Technology, the National Governors Association, and numerous scholarly journals have all reached the same conclusion: the United States is not developing enough science, technology, engineering, and mathematics (STEM) scholars to maintain its role as a world leader in science and innovation. In fact, the National Science Board reports that over "half (51 percent) of the world's share of STEM researchers now live outside the United States and the 27 EU-membered countries."[1] Asian countries, specifically China, are awarding more first university degrees in STEM and have tripled their number of STEM researchers.[1]

The need to infuse STEM into our students' minds and lives could not be greater. According to the National Research Council, primary and secondary school students spend only 18.5 percent of their waking hours in a formal learning environment receiving instruction on multiple of subjects.[2] Therefore, more informal STEM learning opportunities outside of the classroom are paramount. The Cyber Innovation Center, along with its education partners, has developed its own informal education program in order to engage more students in innovative, hands-on, team-oriented STEM learning. The program is called the Regional Autonomous Robotics Circuit (RARC).

Foundation of Project

In 2008 teachers at a local middle school and local high school noted their own students' desire for STEM education beyond the classroom and began an annual robotics competition, which was held at the end of the school year. The Cyber Innovation Center recognized the potential of exposing a greater number of students to STEM learning opportunities and partnered with the founding schools on the 2010 and 2011 competitions. With the Cyber Innovation Center's involvement, the annual competition grew to 43 teams from approximately 13 schools in 2010 to 56 teams from 26 schools in 2011.

While the increased participation in the annual competition was a clear indication of the demand for informal STEM education, the Cyber Innovation Center also received requests from both administrators and teachers for more opportunities to engage their students in hands-on STEM learning throughout the academic school year. Thus, the Cyber Innovation Center decided to expand the annual competition held each May to a circuit that included four competitions offered throughout the school year called the Regional Autonomous Robotics Circuit. The competitions are open to any students in grades 4-12 throughout the region.

The requests to the Cyber Innovation Center from local school administrators and teachers for additional informal STEM education opportunities were the result of few other opportunities in the region. While many local middle school teachers praise the FIRST® LEGO® League, they indicate that the structure of the competition causes them to limit the number of students who can participate. Teams for the Louisiana FIRST® LEGO® League are restricted to ten team members ages 9-14 years.[3] The cost for one team to participate in Louisiana FIRST® LEGO® League include an annual team registration fee of $225, an annual field set at $75, a $20 fee for the local qualifier competition, and a $25 fee for the state championship.[3] Thus, the total annual cost of one team to participate from start to finish is $345. Additionally, the state championship tournament is held five hours from our local community and requires travel costs for any local team that advances to that level. These overall costs cause many schools to register just one team of ten students. The schools' investment allows the teams of ten students to participate in one local qualifier competition in November with hopes of advancing to the state championship in December. Additional competitions are not available for the spring semester unless a team advances to the national competition in April. Beyond Louisiana FIRST® LEGO® League, other STEM competitions are limited in the region and would require travel costs in addition to any registration and equipment fees.[4]

Project Description

The Cyber Innovation Center's response to the need for quality, informal STEM learning opportunities in our region is the Regional Autonomous Robotics Circuit. RARC is a circuit of four competitions offered throughout the school year. Each competition builds upon one another and contains multiple challenges. In order to provide a context for the content, liberal arts are

also incorporated into the challenges. The hands-on challenges serve a dual purpose: introduce STEM concepts and its many applications to younger students and reinforce STEM fundamentals learned in the classroom for older students.

RARC competitions are strategically scheduled throughout the school year in consideration of the academic calendar year. For example, the 2012-13 RARC competitions are scheduled as follows: Saturday, September 29, 2012; Saturday, November 10, 2012; Saturday, February 9, 2013; and Saturday, May 4, 2013. Teams may participate in as many competitions as they choose; participation in all four competitions is not required. Competitions have three divisions for students in grades 4-12: elementary, middle, and high school. Schools and organizations may register as many teams as they wish through an on-line registration system hosted by the Cyber Innovation Center. Each team may have a minimum of two and a maximum of six students; all students on a team must be in the same division.

The Cyber Innovation Center has been diligent to offer a first-class experience for the students and teachers while keeping the event costs low so that each team pays a nominal registration fee of $25. A survey of participating teachers indicates that the registration fees are paid through school funds, club dues, grants, and donations. Only two out of forty teachers reported that the students are asked to contribute to the registration fees themselves.

The registration fees offset the event expenses for the current year and early expenses for the following year. Event expenses include, but are not limited to, the following: paper for handouts, cardstock for certificates, toner, team folders, name badge supplies, refreshments for judges and volunteers, security, awards, and challenge equipment. These costs can vary depending on the number of registered teams and the challenges. Our local community generously donates the facility while the Cyber Innovation Center contributes its staff's time in the planning and execution of the competitions. RARC has become self-sustaining and now offers opportunities for future expansion.

Challenge Design

The challenges within each competition are designed by a committee comprised of Cyber Innovation Center staff members, two high school teachers, two middle school teachers, two

elementary school teachers, one representative from Sci-Port: Louisiana's Science Center, and a liaison between the local school systems. Most competitions include two or three STEM challenges and one liberal arts challenge per division. The STEM challenges require teams to follow the engineering design process. Through this process students learn basic sciences, mathematics, and engineering principles including, but not limited to, the establishment of objectives, construction, analysis, testing, and evaluation.

The platform used in the STEM challenges is merely a tool in the engineering design process. A robotics platform is commonly used in the challenges, which appeals to all grade levels and allows the challenges to be hands-on. Typically, elementary and middle school teams use the LEGO® MINDSTORMS® NXT while high school teams utilize the Parallax Boe-Bot®. Teams use these platforms because they are readily available in the regional schools, but RARC does not restrict the use of other robotics platforms if schools do not have the LEGO® and Parallax products available. Furthermore, future challenges may not utilize robotics platforms; instead the challenges may allow students to use platforms such as manila folders or wood.

While the STEM challenges focus on the engineering design process, the liberal arts challenges provide the context for the content and utilize students' 21st Century Skills. For example, in the *Robots in Our Lives* challenge, elementary school teams are asked to create a static display board to showcase their research about a robot that is used in everyday life. The display board must include the following: description of the task(s) that the robot accomplishes; description of how the robot makes a job easier; a history of the robot, e.g., who invented the robot, where is it used, etc.; and illustrations or images of the robot. Through this challenge, the students see that robots (STEM) are all around us and understand the positive impact they have on our daily lives. The students then use their writing skills and organization skills to create a clear and informative display board that conveys what they have learned about the history of the robot, its inventor, and its function. Because creativity is always encouraged, students also produce illustrations or images of the robot and decorate their boards with vibrant colors and borders. Like the STEM challenges, the liberal arts challenges are hands-on and fun as well as educational for the students.

The guidelines for the challenges are released 4-6 weeks prior to each competition to allow teams time to prepare. Teachers can integrate these project-driven challenges into their classroom curriculum, or they can use the challenges as curriculum for their afterschool clubs and programs. The majority (62%) of students on competition teams are members of robotics clubs that meet after school. Twenty-one percent of the remaining students volunteer or compete to participate on a team while 13% are required to participate in the competitions as part of a STEM class. A small percentage of students participate in the competitions as part of an afterschool tutoring program or as part of an elective course at school.

The majority (60%) of teachers report that they have 0-2 hours each week to help their students prepare for the competitions. Thirty-three percent of teachers indicated that they have 3-5 hours per week to work with their teams. Only 7% of teachers have 6-8 hours a week to coach their teams.

The scoring guidelines are released with the challenge guidelines so that teams have a clear understanding of how they will be judged. Teams receive points for each challenge and then a cumulative score based on their performance in all the challenges at the competition. Trophies are awarded at each competition to the teams with the three highest scores in each division.

Teams are then ranked in order from most to least points and receive points towards their overall circuit score according to their ranked position. For example, Smith Elementary Team 1 has the highest score in the elementary division. That team is awarded 1,000 points. Jones Elementary School Team 3 has the second highest score in the elementary division and is awarded 990 points. This point allotment continues for all the teams in that division and is replicated for the teams in the middle school and high school divisions. The points earned by each team throughout the four competitions accrue. The team with the most points in each division at the end of competition 4 is named the grand champion of that division. Grand champions earn a technology award for their classroom in addition to a prize for students (such as a pizza party).

Sample Challenges and Activities

Below are samples of STEM and liberal arts challenges and activities from the 2011-12 and 2012-13 RARC competitions.

***Tug-of-War**:* This challenge requires an understanding of torque, force, and friction. Teams must program their robots, connected to an opposing team by a tow rope, to pull their opponent's robot across a center line. Teams compete for first place using a bracket system.

Fire-Fighting Simulation: For this challenge, teams must understand the concept of input/output through the use of sensors. Teams program their robots to autonomously navigate a competition board designed like a house floor plan and utilize sensors to locate and fight "fires," red balls, strategically placed in rooms.

***Mystery Challenges**:* Teams are required to use the skills they developed throughout the 2011-12 circuit in a series of three challenges. First, teams assemble a robot that autonomously traverses a complex maze. Next, teams have thirty minutes to modify their robots to detect oncoming threats and then engage those threats once they break a threshold. Lastly, students are given a box of parts and are required to build a mechanism to move cargo from one point to another while overcoming obstacles. Students are not aware of the challenges they are going to face when they arrive at the competition. Rather, teams receive hints regarding the challenges in the weeks prior to the competition to allow them to predict and hone the necessary skills for the challenges. Then teams must develop a final strategy as each challenge is revealed at the competition.

On Thin Ice: This challenge showcases basic sensor design and robot control systems in the form of a small autonomous robot which must follow a black line over a white surface. The course includes straightaways, turns, and crossings, but the exact details of the course are not revealed to the teams until the competition.

Tractor Pull: This challenge teaches students concepts of kinetic energy, friction, and inertia as well as forces them to make educated decisions on the capability of their robot. Teams must program their robots to autonomously pull a clipboard stacked with tomato soup cans down a lane ten feet in length in the fastest amount of time. Teams are able to choose how much weight (how many cans) to load on the clipboard.

***Pac-Man**:* This challenge requires teams to develop critical thinking and analysis skills. Teams must use logic and reasoning to plan the approach and execution of this challenge. Teams

program their robots to autonomously enter a maze lined with marbles, knock as many marbles as possible from their placements, and exit the maze in three minutes or less. White and yellow marbles are worth different point values so teams must develop a strategy of which path from entrance to exit will yield the most points.

Mine Sweeper: Teams must accomplish three missions within five minutes of entering the mine field board. Those missions are to locate eight land mines using a Hall Effect sensor and indicate the mine was detected by sound, blinking LED, etc.; find the enemy's general using an infrared sensor and knock him down; and locate and raise the American flag by entering the American base. Points are deducted for false positives when locating hidden mines.

Teamwork Photos: Elementary school teams submit photos that depict the concept of teamwork. Creativity is encouraged. Photos are displayed on the Cyber Innovation Center's webpage.

Engineering Design Process Display: Middle school teams create a static display board to chronicle their use of the engineering process for building and testing their competition robots. The rubric for this project requires the teams to answer the questions in each step of the engineering process, include pictures of the teams constructing their robots, and utilize organization and creativity skills to format and decorate the display.

Instructional Video: Middle school teams create an instructional video on a skill used in the Tug-of-War or On Thin Ice competitions. The approach should be that of mentoring younger competitors by teaching key robotic concepts. Teams record and edit the videos using software such as Windows® Movie Maker.

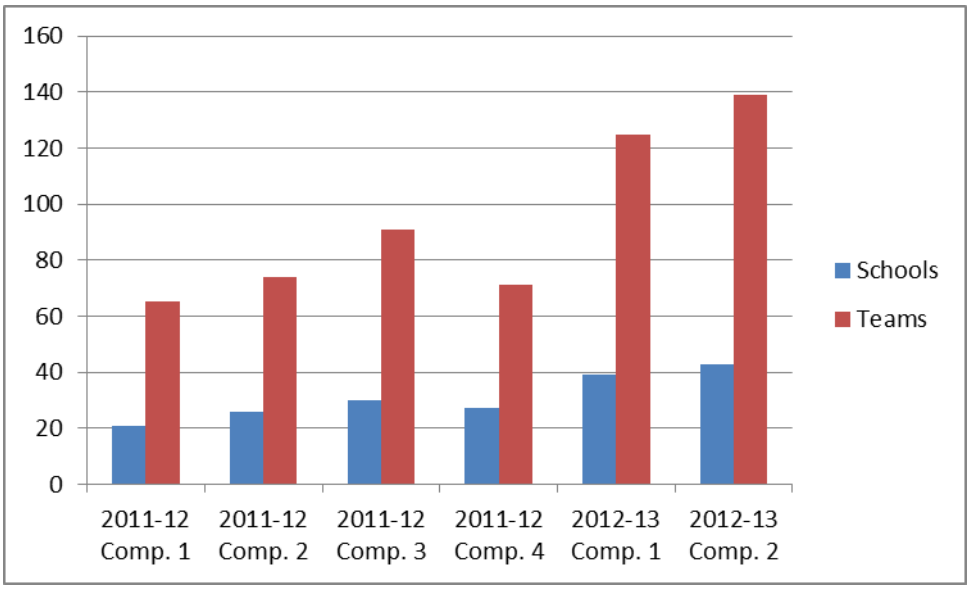
Technical Presentation: High school teams are required to give a PowerPoint® presentation on the Pac-Man challenge as if they are meeting with a company to sell the idea of their robot. Teams address topics such as how their approach to meeting the challenge is unique or best, how they designed any accessories, how they overcame obstacles, and what each team member's role is in the process. Organization, clarity, and creativity are encouraged.

Technical Writing: High school teams must plan, design, and articulate in written form a proposal for a robotics competition that is unique to RARC. The proposal includes a budget and a graphic design of the layout of the competition.

Company Demonstrations*:* Local STEM-related companies and organizations are invited to attend the competitions and provide demonstrations to students on the real-life applications of the skills they learn through RARC. For instance, representatives from the local military base and representatives from the city fire department's bomb squad have offered dynamic demonstrations for the students.

Results

RARC began in September 2011 and has experienced significant growth in overall participation as well as high satisfaction ratings from teachers. Please see the chart below that illustrates the participation of schools and teams from September 2011 to November 2012.



Thirty-seven different schools from seven parishes participated in the 2011-12 RARC with 508 students in grades 4-12 benefitting from the program. The average number of teams for the 2011-12 RARC was 77. Of the 508 participating students, 16% were female and 84% were male. Additionally, 18% of students were from underrepresented populations. The 2012-13

RARC began with Competition 1 in September 2012 and Competition 2 in November 2012. Competition 2 boasts the highest participation numbers yet with 139 teams from 43 schools from 6 parishes across the state. Thus far, a total of 712 students have competed in the 2012-13 RARC. In addition to an increase in schools, teams, and students, the number of female participants has increased to 25% and the number of underrepresented students has grown to 26%. With a well-documented disparity in female and minority populations[5], the Cyber Innovation Center is encouraged by the increasing number of female and underrepresented populations at this year's competitions.

The following are the results from a survey disseminated to participating teachers after Competition 2 in November 2012. Teachers were asked to respond to questions below with one of the following answers: strongly agree, agree, neutral, disagree, or strongly disagree. Forty teachers offered responses.

Question	Strongly Agree	Agree	Neutral
My students are challenged by the competition.	53%	43%	3%
The competition helps reinforce the STEM concepts taught in the classroom.	18%	67%	15%
The competition introduces new STEM concepts to the students.	29%	47%	21%
The competitions are valuable informal learning opportunities for my students and me.	50%	43%	7%
My students enjoy participating in the competitions.	50%	45%	3%

One teacher offered an additional feedback by commenting, "I find that these type of competitions not only teach STEM concepts but life skills such as effective communication, conflict resolution, and leadership." The overwhelmingly positive responses offered through this anonymous survey provide validation that RARC is achieving its purpose of introducing STEM concepts and its many applications to younger students and reinforcing STEM fundamentals learned in the classroom for older students.

The survey also reveals that the teachers who help prepare the students for the competitions are in need of additional professional development. The majority (55%) of teachers have ten years' experience while 21% have 5-10 years, 21% have 3-5 years' experience, and 3% have 0-2 years' experience. Yet when asked their level of robotics experience, 43% rated themselves as beginners, 43% rated themselves as intermediate, and only 15% rated themselves as advanced. The RARC committee has tried to address this need by encouraging teachers to attend robotics workshops at Sci-Port: Louisiana's Science Center and by asking teachers with advanced robotics experience to mentor teachers who are beginners. Additionally, one committee member is a liaison between one local school system and Sci-Port: Louisiana's Science Center and works with the teachers from many of the participating schools. Still, a more concentrated effort to teach the platform basics seems necessary.

Conclusion/Future Directions

The Regional Autonomous Robotics Circuit is currently in its second year. The program has been well-received by administrators, teachers, parents, and students and their feedback indicates positive short-term results. The long-term effects of this informal STEM learning program will be determined in the years to come. The feedback received thus far also provides the Cyber Innovation Center with an opportunity for improvement for the program. Based on the teachers' need for more professional development, the Cyber Innovation Center plans to host multiple professional development workshops for teachers starting with the 2013-2014 RARC. These workshops would be offered at no charge to ensure maximum participation. The Cyber Innovation Center has also secured grant funds to purchase robotics equipment and cover registration fees for schools with economic disadvantages.

Other regions are aware of RARC, and multiple communities have approached the Cyber Innovation Center regarding replication of the program in their communities. As a result, the Cyber Innovation Center has created a franchise model that allows it to cost effectively deliver RARC in other communities while managing the logistical matters, which can serve as hurdle to expansion. The Cyber Innovation Center plans to expand RARC to at least one additional region in the 2013-2014 school year and more regions in outlying years. This expansion is expected to occur both within and outside the state.

Acknowledgements

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