Think Outside the Bots

By Diane McGrath with Bill Rust and Kevin Kramer

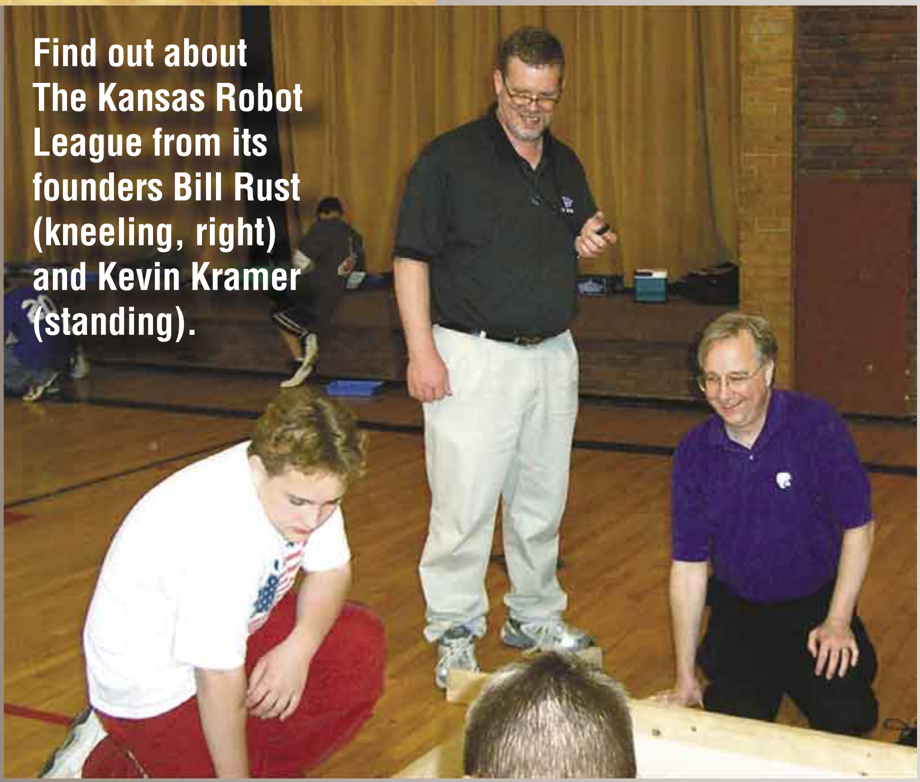
Subject: Robotics, programming, math, science

Audience: Teachers, teacher educators

Grade Level: 5–12 (Ages 10–18)

Technology: LEGO Robot Inventions System (RIS) and Robolab Team Challenge

Standards: *NETS•S* 3, 5, 6 (http://www.iste.org/standards/). *NCTM* Grades 6–8 and 9–12 Geometry, Measurement, and Problem Solving (http://standards.nctm.org/document/). *NSES* Science Content Standards Grades 5–8 and 9–12 B (http://books.nap.edu/html/nses/html/).



Find out about The Kansas Robot League from its founders Bill Rust (kneeling, right) and Kevin Kramer (standing).

Last week, some space opened up in my schedule, and I grabbed the opportunity to go out to a rural school to see a meet between two schools' robotics clubs. I was eager to see the Kansas Robot League, started in 2000 by two Kansas State University (KSU) doctoral students: Bill Rust and Kevin Kramer.

This month, I describe the robotics meet as one kind of project-based learning (PBL) activity with technology at its core.

PBL and Robotics

Before we look more deeply into what goes on when kids build and program robots, let's first examine the features of PBL that are part of the robotics competition and see what happens in such a meet.

"Being on a team is a tremendous educational experience, and many kids, particularly bright ones, don't get involved in sports and so don't have the experience. Providing a team experience in an academic context, where different talents are required for success, is novel."—*Bill Rust*

The *driving question* in a robotics challenge is a combination of engineering design issues and programming issues. Three types of challenges were offered in the meet I attended: the Sumo, the Maze, and Capture the Flag.

The *artifact* is of course the robot, with its downloaded program, both of which may be designed, redesigned, and modified on the spot to meet the opponent's challenge. These *technology tools* become a means of externalizing one's ideas and testing them out.

Although only one person actually runs the robot during a challenge, there is a team behind that person. The team *collaborates* on the design and programming of their robot, each team member contributing ideas for modifications based on what they just learned about the success (or lack of success) of their robot and others' robots during a challenge. The challenge itself provides one type of *assessment:* immediate feedback about whether a team's design works and whether it works better or faster than the opposing team's robot. Teams learned from each other's robots and got excited about a robot that was good, even if it wasn't their own. These observations suggest both the importance of an authentic *audience* and the nature of a *community of inquiry* in the context of a competition. In addition to the community nature of the competition, online resources are available for teams and individuals to *research* and to enable them to become part of a worldwide robotics community. (***Editor's note:*** See the Resources section on p. 51 for some of these URLs.)

Q&A with the League Founders

To get a firsthand account of the startup, funding, goals, and outcomes of this league, I talked to Bill and Kevin, who continue to put their own energies, ideas, money, and time into building the league's success.

L&L: What are the requirements to belong to the Robot League?
Bill: Anyone in Grades 5–12 can form a team and join. It's open to homeschoolers as well as regular schools. The only requirement is that the teams participate in at least one meet during the year. We have been giving 2–3 kits to each school that joins.

L&L: What does it cost, altogether, for a school/classroom/club to belong?
Bill: The 2–3 kits that we supply a school are enough to support 10–12 students. Additional kits are approximately $200, and you need one for each 3–5 students. Because this tends to be an after-school activity, it may also be necessary to provide a teacher with extra-duty pay. There is the issue of transporting students to the meets and providing a substitute for the supervising teacher. The robots require rechargeable batteries, which cost approximately $40 for each kit. Computers are required for programming, but most classrooms already have an adequate computer. (***Editor's note:*** See Necessary Equipment and Software on p. 48 for more detailed information.)

L&L: What do you do in this league? How often? How many kids and teachers are involved?
Bill: You build and program robots to do certain tasks, either in a classroom unit on robotics or in a club after school once a week. The club or classes will face off whenever two teams have completed a robot. Because one of the fundamental principles of the league is to make the contest areas cheap to build, schools frequently have their own mazes and sumobot rings. After you build them and test them out, you bring them to a challenge meet and see how well your robot does against other robots. There is one major meet a year during the KSU Open House. This year, we have had about five smaller meets sponsored by individual schools.
Kevin: Currently, more than 40 schools from across the state participate in the program, reaching to approximately 500 students and 50 teachers. This last year, we offered a teacher workshop. How actively a school participates is up to the teacher.

L&L: What are your goals for this league?
Bill: My goals are twofold. First, I would like to see this develop into a state-sanctioned, interscholastic activity, in the mode of track or debate. This would be a first for young kids, elementary age, to have state champions. Being on a team is a tremendous educational experience, and many kids, particularly bright ones, don't get involved in sports and so don't have the experience. Providing a team

Necessary Equipment and Software

Two robotics kits are commonly used in these competitions: the Robot Inventions System (RIS) and the Robolab Team Challenge kit. Both kits use object-oriented and graphical programming languages.

The PC-based RIS includes the LEGO RCX brick (the programmable LEGO computer that is the core of each robot), sensors (the basic kit comes with sensors for light and touch), motors, and about 700 LEGO pieces. The programming language used by RIS 2.0 involves the use of drag-and-drop modules. One RIS costs approximately $200. Your computer should have at least a 300 MHz Pentium II processor and run Windows 98 or later.

League members may also use the Robolab kit and Mindstorms for Teachers software. This kit and software also costs about $200. The Robolab series contains LabVIEW software for more control of the RCX and a variety of RCX-based kits oriented toward school use. Robolab runs on both Macs and PCs. PCs should have at least a 300 MHz Pentium II processor and run Windows 98 or later. Macs should have at least a 166 MHz PowerMac processor, and run System 9.0, with 32 MB RAM, 165 MB free disk space, and a free serial port (either legacy or USB).

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> ***—Kevin Kramer***

experience in an academic context, where different talents are required for success, is novel.

Second, I want to see schools restructured. When I was growing up, math and science were taught as established facts. Both could be pretty boring. But most mathematical techniques were developed to solve problems that were very important to the people of the time. And physics was all about solving problems in the real world. Building robots for competition puts relevance and self-generated excitement back into learning these subjects. For example, ratios are used when you connect a robot's wheels to its motors through gears. A high ratio makes for a fast but weak robot, while a low ratio makes for a slow but strong robot. Because these physics concepts become intuitively clear, students can and do test their understandings by modifying the robots to see what they do. This change from passive to active makes the students realize they are responsible for their education.

Kevin: We are a grassroots organization working our way into the school, I share Bill's goal for this becoming an approved KSHSAA [Kansas State High School Activities Association] activity for students to participate in at school.

Given the wide age range for participation, this could become the initial training ground for more advanced robotic activities that other schools around the nation participate in, for example the FIRST LEGO League.

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L&L: What do you think teachers' goals are for taking the time and energy to do this?

Bill: It varies a lot. Some teachers see poor, at-risk kids and are willing to do anything to try to get them connected to school. Because the equipment costs are so modest and this program is new, poor schools are on a much more even footing with wealthier schools than in most activities. Other teachers see this as fun for themselves and a safety valve for gifted students.

Kevin: Teachers are out there trying to find what stimulates active learning. A number of them have seen the value of this activity in and outside the classroom. We have seen an increase in involvement of parents of kids who are active in the robotics class or club in their school. And teachers have reported an increase in academic performance and improved behavior of these students on their regular schoolwork so that they can earn additional time to work on robotics.

L&L: What do you think the kids get out of it?

Kevin: I love to see kids learn from each other. During robotic meets, the greatest learning takes place when students observe students' robots from other schools. Little design changes or modifications to robots occur throughout a competition, each student hoping to find the extra edge to perform better.

Also, I think a lot of students learn what teamwork and leadership are really about. They are learning how to build upon the skills and abilities that each student brings to a team environment to achieve a workable goal. Teamwork requires more than participating at a certain skill level. In our setting, it asks them to question, problem solve, and test their ideas to reach their goal.

And, of course, students get recognition from their peers. Last year, we presented individual medals to winners of Open House Meet. This involved visiting the schools following the meet and presenting the medals to individuals in class. This year, we switched to presenting trophies at the end of the meet, allowing the individual and team efforts to be recognized within the robotics community and to be displayed at the schools of the winners.

Bill: The kids get a variety of things out of it. They are exposed to career opportunities they might not have thought of before. They get to work with other kids and learn how to work in a team environment without adult control. Their end-product is graded not in some seemingly arbitrary process that they may not understand but by a simple win-or-lose match. Learning how to lose in a gracious manner is an extremely important skill, and a robot meet provides a controlled environment in which the outcome of the match does not negatively affect the students' other areas of academics.

L&L: How long does it take kids to understand engineering, design, problem-solving, and programming concepts?

Bill: It takes an amazingly short time. The RIS software comes with a Training Missions section that takes about two hours to complete. Most kids can write simple programs shortly thereafter. Because most kids have already played with LEGO, they can build things in short order. RIS provides designs for several different robots, so some kids immediately start freelancing while others take a cookbook approach. Engineering ideas come into play when a robot runs into a wall or falls off a table. Well-designed robots remain largely intact, while not so well-designed ones break into pieces. Kids with ones in pieces are told to look at ones that held together and figure out why their design failed.

We use the maze as the introduction to algorithm design and programming. I will take a robot with two touch sensors and move it through the maze, describing the various behaviors that it needs to implement. First, I move it down the center of the maze and talk about what it needs to do when it is not running into a wall. Then I run it into the wall on one side or the other and say that it needs to back up and turn away from the wall. Then I have the kids do the same exercise so that they develop a tactile understanding of what the robot needs to do. At that point, I send them off to write a RIS program on their own without further intervention. We then download and test their programs until they have something that more or less works. Then we change the maze and test how robust their programs are. This happens within the first few contact hours.

L&L: What would you like to do with this league that you haven't accomplished yet?

Kevin: Funding! There is a similar program at another university that has corporate and grant funding. It would be great to be able to make 3–5 kits available to schools that wanted to participate in the league. We're limited in the number of kits we can provide at startup. Most of our schools have to find additional sources of income (parent-teacher groups, activity funds,

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or private resources) to purchase more kits to meet the demands of the students who want to participate.

In addition, I would love to see more time to introduce this program to teachers and administrators and to provide inservice training so they feel greater confidence in the subject matter and how it can be applied across the curriculum.

Bill: The RCX is an embedded microcontroller with hundreds of applications for real-time monitoring that will provide students with an unprecedented ability to explore the real world. This exploration will force them to learn about math and science in context while concurrently facilitating them in changing their attitude about learning. It will, for many students, change school work into school fun.

In order to do that, we need buy-in from teachers. School reform has frequently failed because it has been imposed upon teachers. In Robot League, we have teachers who are going nuts in curriculum development. They are making posters saying "torque is …" and "power is …" and "gear ratios are …". This is happening in sixth-grade classrooms. We need to support those teachers. We need to get lesson plans done on how using robots fits with state standards. We need a Web site to serve as a repository for the growing curriculum base. For the next three summers, we have an NSF-RET [National Science Foundation Research Experiences for Teachers] grant that will provide support for the teachers to come to campus and learn about robotics. As part of this summer course, teachers will go through the Kansas mathematics and science standards and explicitly make the connections to robotics. This will allow us to use the professional knowledge

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of these teachers to create a document that is better understood by teaching professionals. We want those teachers to form a cadre that will demonstrate that ordinary teachers can really use this stuff. Grant participants are required to create a presentation to give at either state technology conferences or at their own district's inservice meetings.

Ready to Join In?

With such a very low cost for a kit, why not join in this highly motivating type of project, either as a unit in your curriculum or as an after-school club. Bill and Kevin approached this one school at a time. You can do that, too! Write and tell us what you are doing with robotics in your school. Send comments to letters@iste.org.

Resources

In addition to Diane McGrath's PBL Web site (http://coe.ksu.edu/pbl/), which expands on resources mentioned in the PBL columns, with annotations and further links, you may also find the following resources useful.

First LEGO League North America: http://www.firstlegoleague.org/sitemod/design/layouts/default/index.asp?pid=70

Kids Learning Engineering Science Using LEGO and the Programmable Brick: http://web.media.mit.edu/~fredm/papers/aera96/

Kids Online Resources—Science, Robots and Robotics: http://www.kidsolr.com/science/page1c.html

LEGO Mindstorms Internals: http://www.crynwr.com/lego-robotics/

LEGO.com Mindstorms Home: http://mindstorms.lego.com

Robotics: http://news.lugnet.com/robotics/

Robotics Education Project: http://robotics.nasa.gov/

Robotics Learning Home: http://www.roboticslearning.com/

Unofficial Questions and Answers about MIT Programmable Bricks and LEGO Mindstorms: http://fredm.www.media.mit.edu/people/fredm/mindstorms/

The Robot League at Kansas State University: http://www.educ.ksu.edu/robots/

Diane McGrath is an associate professor of educational computing, design, and online learning at Kansas State University. She is former editor of the Journal of Computer Science Education *(now published on ISTE's SIGCS Web site as JCSE Online) and the* Journal for Research on Computing in Education *(now the* Journal of Research on Technology in Education*), and she has written a number of articles related to technology and higher-order thinking for ISTE periodicals.*

William Rust is a software engineer currently working on a PhD at Kansas State University specializing in educational computing, design, and online learning. Before returning to school, he was an executive at a networking company and a consultant in freight transportation. He holds an MA from Tufts University in education and an SB from MIT in civil engineering.

Kevin Kramer is a continuing education instructor at Manhattan Area Technical College and a graduate assistant for the Department of Computer and Information Science at Kansas State University. He is also a doctoral candidate at KSU, specializing in educational computing, design, and online learning. He holds an MS in secondary education from KSU, a BS in human ecology and mass communications from KSU, and a BS in industrial education and social sciences from Emporia State University.