FIRST LEGO® League, the sport of the mind

Gifted children need daily challenge in their area of strength to thrive (Rogers, 2007). With estimates of gifted students underachieving ranging from 10-50% (McCoach & Siegle, 2008) and forming 25-30% of high school dropouts (Kim, 2008), and less than half of gifted underachievers finish four years of college (McCoach & Siegle, 2008), challenge is important. Compounding this issue, many aptitude and achievement tests emphasize math and reading, and few school programs identify talented students outside of those domains. Thus, students with spatial gifts are often neglected in school curricula and instruction and may not be challenged in their talent area at all in school, potentially leading to underachievement.

According to Rebecca Mann (2006), an assistant professor at Purdue University, students with spatial gifts tend to be undereducated and underemployed as adults when compared to students with similar gifts in mathematical and verbal areas. This is particularly alarming since people with spatial strengths may be highly suited for careers in engineering, architecture, physics, design, medical surgery, and the arts. However, academic competitions involving spatial challenges are an excellent way to meet the needs of students with high spatial abilities. Academic competitions such as FLL, Odyssey of the Mind, and Academic Decathlon, help to motivate highly able students and challenge them to give their best efforts. One of the best is the FIRST LEGO League (FLL).

FIRST is the foundation For Inspiration and Recognition in Science and Technology. The not-for-profit organization "designs accessible, innovative programs that motivate young people to pursue education and career opportunities in science, technology, engineering, and math, while building self-confidence, knowledge, and life skills" (US FIRST, 2008). The foundation sponsors the FLL for ages 9 to 14 years as well as the new Junior FLL for ages 6 to 9 years and

two high school level robotics programs. FLL is an international competition taking place in more than 40 countries and involving more than 13,500 teams with an approximate total of 135,000 students participating in the 2008/09 competition year (US FIRST, 2008). Each year, a new real-world science topic is chosen. Recent topics have included nanotechnology, Mars, energy production, transportation, and global climate change.

Using robotics in the classroom, whether students compete in the competition or not, has many academic benefits. Designing, building, and programming a LEGO robot pushes students' spatial reasoning and creative problem solving abilities (Waks & Merdler, 2003). As students are actively engaged in science, technology, engineering, and math (STEM) fields, they may become more interested in such careers and begin to pursue advanced classes in those subjects earlier. Students involved in the year's science topic become active researchers, turning the year's science topic into a tangible and meaningful inquiry experience that should then be shared with a real world audience.

Research-based Educational Benefits

Participation in FLL has resulted in outstanding outcomes, as determined in several studies conducted by the Center for Youth and Communities (CYC) at Brandeis University. The CYC found that 94% or more of all students participating in FLL had increases in the following areas: interest in science and technology, programming skills, understanding of how science and technology can solve real world problems, problem-solving skills, teamwork skills, leadership skills (Melchior, Cutter, & Cohen, 2004). A separate study by CYC, focusing on college outcomes of the FIRST Robotics Competition (FRC) (the high school level program), found that when compared to a control group of students with similar backgrounds, FRC participants were: 1., 35% more likely to attend college, 2., twice as likely to major in a STEM field, 3., nine times

as likely to have an internship during their college freshman year and 4., twice as likely to perform community service (Melchior, Cohen, Cutter, & Leavitt, 2005). The FRC is, of course, a big step up from FLL, but since it is very similar in the processes undertaken by students and each competition is appropriately challenging to its respective age level, the study sheds light on likely long-term outcomes for FLL participants as well.

Participating in FLL

Forming a team

Teams of 3 to 10 kids, ages 9-14 (as of January 1st of the competition year) can participate. Any group can form a team—a school, an organization (such as Scouts or 4-H), or a neighborhood group. A two-year team cycle is suggested. In this cycle, fifth graders move on to middle school and the fourth graders become fifth graders (veteran members). The team can then draw new members primarily from rising fourth graders, up to ten members—the maximum allowed under FLL rules. For a new coach, it's recommended to start with about six students in the first year. Consider organizing the team with a multi-year focus—members will gain the most benefit from going through multiple years of challenges and competitions as well as gaining the ability to mentor new members.

Many methods can be used to select members for a team. In our case, new members are found by hosting a "Spring Challenge" in which the competition team from the previous fall (the veterans) hosts all interested students in a series of mini-competitions late in the school year. Normally there are about 50 students interested in the challenge, mostly among third graders. These neophytes are spread out into groups of about eight or nine, each group meeting for an after-school session of two days in the same week for an hour and a half per day. A past challenge set such as "Mission Mars" or "Ocean Odyssey" is utilized, but a unique challenge

could easily be created by students. Notes are kept on each student to determine who may be ready for the competition team in the fall. A short challenge like this is an excellent way to see who may be ready to participate in the competition.

In the fall, as the school year starts, applications are sent to everyone who participated in the spring challenge. Some students find in the Spring Challenge that FLL is not for them and some may have other fall commitments that interfere with the practice schedule. Of those 30 or so applications that are returned each year, care is taken to select students who exhibit the maturity and aptitude for the challenge.

Competitions

Competitions generally last from early morning until mid-afternoon on one day. Championship Tournaments are sometimes multi-day events. Preparing for competitions consists of two main parts, the robot game and the project, but judging also encompasses teamwork and robot design. Each category is counted equally, so it's important to encourage the team to do their best in each area.

The Robot Game

Imagine a series of 4'x 8' tables in a large gymnasium filled with noisy on-lookers. The tables are covered with LEGO objects such as a windmill, a catapult, a truck, and many other creations. Beside each table, there are two students with their hands on a white LEGO robot. A referee counts down: "3-2-1-LEGO!" One student pushes a button on the robot and it takes off on its first set of missions, moving an object from one place to another and then uses an arm to grab another object and drag it back to base. The students pull the arm attachment off the robot, add some different pieces, then launch the robot again to complete more missions. The crowd

goes wild. This is the robot game at a FLL competition, and likely the reason that FLL is sometimes referred to as "the sport of the mind."

In essence, each team brings a prepared robot to competition (see Table 1 for more information on what to bring). Teams will have the time between receiving the year's missions in early September (released to the entire FLL world on the same day internationally) and the regional qualifying tournament to design, build, and program a robot to complete as many missions as it can in a limited time. Each team has four opportunities of only two and a half minutes to place the robot on the table in the area designated as base. and launch a series of prepared programs to manipulate the objects on the table for points. The highest score among the four attempts is a team's final score for the robot game portion of competition. In robot design judging, the team will go to a group of judges to demonstrate their understanding of their programs and robot's design at a standard FLL table with the year's challenge set up. The judges also will ask questions to get at the heart of the competition: How the team problem-solved to overcome difficulties—both in engineering and programming their robot. This judging also serves as a safety valve, ensuring that the students—not their coaches—did the work.

The Project

In the 2007 competition, Power Puzzle, our team debated possible topics and chose, in the end, to perform an energy audit on the town's new town hall. We invited a professional energy auditor to our school who demonstrated energy auditing techniques in a classroom, discussed important things to look for in an audit, and helped generate questions to ask on our first town hall trip. There, we were guided around the facility by the assistant town manager who answered the team's many questions, going as far as to e-mail the insulation rating after our visit. The team brought back piles of information and spent much of the next several weeks doing

Internet research as well as following up with the energy auditor and assistant town manager. As our team is divided into mini-teams, one mini-team would go with a parent volunteer to work on their research in our school's computer lab. As with the robot game, our team worked to synthesize their research and form a presentation in the weeks approaching competition. They prepared a poster using giant puzzle pieces (a nod to the year's theme) that each had problems with energy use in the town hall on one side and possible solutions, costs, and likely effectiveness on the other side. The presentation was given to the Town Council at their next meeting, which happened to be just a week before competition.

Judging focuses on ensuring that the students did the work. Coaches are allowed to attend the judging session, but not allowed to participate in any way. Having shared the information with others in the community is also important, as in my example with the Town Council. Emphasis is also placed on creativity—both in the solutions and in the presentation itself; neither well-known solutions nor students just reading word-for-word from computer-generated slides will suffice. Some teams do skits and other theatrics, which can work very well, provided that the team demonstrates their research.

Teamwork

Teamwork judging varies by locality. While many areas choose a teamwork winner with roaming judges looking for signs of strong or poor teamwork during the course of the day and with questions about how each team worked together in a separate judging session, many areas now have a teamwork challenge. Unknown in advance, the judges in this session present an open-ended problem to each team and then observe the teamwork in attempting to solve it. Still, regardless of how it is judged, teamwork is a virtue espoused in the FLL Core Values (see Table 2).

Preparing and Coaching for Competition

A great deal of preparation is needed prior to creating a robot and solving missions. Four main things need to happen between registration and beginning work on the robot.

1. At the very least, each team needs a computer, a LEGO Mindstorms® NXT robotics set (which includes the software and can be purchased at many places online, including when registering a team), and a standard FLL table.
2. Have some members of the team build all of the objects in the field kit, which will also be sent after registration. This should be done as early as possible, as it takes time and work toward solving the missions cannot be done until this step is completed. Coaches should carefully inspect all objects to ensure that they are built according to the instructions.
3. Have the students go through the programming tutorials available on the CD-ROM included with the NXT kit. In order to go through the tutorials, team members will need to build a basic robot, such as one from the included instructions. However, the team should build a unique robot specifically for the challenges later.
4. Get the team working together as a team. Utilize team-building activities—whatever helps build the team members' relationships with each other. The challenges they will face with designing, building, and programming a robot to complete missions and in creating the project (discussed below) can become frustrating and the pressure at the competitions can become overwhelming to a group of students who are not centered in a team that works together to problem-solve and overcome challenges.

FLL teams register over the summer or in the early fall. Qualifying Tournaments (often called "regionals") are usually held in November or December with Championship Tournaments

generally scheduled in early December or January. During most of the weeks between the challenge release and the regional qualifying events, teams should meet as many times as possible.

Our team meets as many times as possible for several extra hours in the evenings immediately before a competition, incorporating a pizza dinner in the middle of practice. In the final three weeks, the team must load all programs onto one robot; however only two team members are allowed at the table at a time at the competition. In our case, we first load the programs onto the other robots, as back-ups in case our primary robot is accidently dropped. Then we practice a "pit crew" where all team members organize into pairs, each with a specific mission to run a few specific tasks. One pair launches the first program to solve the first set of missions, they move away from the table as the robot returns to base and the next pair steps up to swap attachments and launch the next program, repeating the process so that all team members participate in the robot game each time. While few other teams do this, this particular practice has been very successful at competition and popular within the team, but it must be practiced regularly before competition to be successful.

Coaching

My rule of thumb has been: stop telling and start asking. Asking questions and encouraging students to ask questions is inquiry-based learning. Instead of telling a student how to strengthen part of their robot, ask them what they might do to keep it from falling apart. Instead of telling a team part of their presentation is weak, film them, let them watch their presentation, and find out what they think. A coach's work should include asking questions to aide student understanding, facilitating teamwork and sportsmanship (called "gracious professionalism" by FIRST), keeping track of time—both of practice and in being prepared for

competition, registering the team for competition, managing volunteers (parents, university students, etc.), ensuring that resource needs are met (managing the team's finances), ensuring organization, acting as referee in practice runs for the robot game, and arranging guest speakers and field trips as needed for the student-determined project. Coaching does not involve building robots and programming them or researching and creating a presentation for the year's topic—those are the students' jobs!

Finding Funding

Funding is always a question brought up by new and potential coaches. Generally, with the cost of the NXT kit (which includes the software), building the table, team registration (which includes the field objects and mat for the year), and competition registrations, a new team can expect to spend about $850. The NXT kit and table are reused each year, so returning teams generally find that they spend about $400 per year.

Universities can be sources of support. Virginia Tech, located just fifteen minutes from our school, provided both a robot kit and a computer for our first year. More importantly, the university developed a mentoring program where both undergraduates and graduates in STEM fields received training in FLL and came to most of our practices each season to work with students.

Our team has been fortunate to have a supportive school board office that provided a robot kit and a PTA that has paid our team registration each year. A letter is sent out to parents of team members with a list of financial needs at the start of each season, which have always been met with donations small and large, often through a parent's business (for which a public school can provide a receipt for a tax deduction). We've also received a grant through our local power company each season for the past several years which has helped us buy additional NXT kits and

pay for competition registrations. Many such grants are out there at the local level. In the end, raising funds for the team varies by locality and has been a group effort made up of many contributions.

Table 1: What to bring to a FLL competition

- A prepared robot, all of its attachments, and a fully charged battery.
- If possible, a prepared back-up robot, duplicates of all attachments, and a fully charged battery.
- A laptop or two with the LEGO NXT-G software and all of the robot's programs.
- A cable to download programs to the robot (a standard USB printer cable).
- The team's LEGO bricks, hopefully organized by type.
- Battery charging cable.
- All project presentation materials, props, and handouts.
- Team t-shirts to wear.
- Snacks and drinks.
- A ball or Frisbee for entertainment and exercise during the occasional lengthy time between events.
- A plan for lunch—some events have lunch available for a fee, but it varies by event.

Table 2: FLL Core Values

- We are a team.
- We do the work to find the solutions with guidance from our coaches and mentors.
- We honor the spirit of friendly sportsmanship.
- What we discover is more important than what we win.
- We share our experiences with others.

- We display Gracious Professionalism in everything we do.
- We have fun! (US FIRST, 2008)

References

Kim, K. H. (2008). Underachievement and creativity: Are gifted underachievers highly creative? *Creativity Research Journal, 20*(2), 234-242.

Mann, R. L. (2006). Effective teaching strategies for gifted/learning disabled students with spatial strengths. *Journal of Secondary Gifted Education, 17*(2), 112-121.

McCoach, D. B., & Siegle, D. (2008). Who are the gifted underachievers? In J. A. Plucker & C. M. Callahan (Eds.), *Critical Issues and Practices in Gifted Education.* (pp.722-726). Waco, TX: Prufrock.

Melchior, A., Cutter, T., & Cohen, F. (2004). Evaluation of FIRST LEGO League. Waltham, MA: Center for Youth and Communities, Brandeis University. Retrieved March 16, 2009 from http://www.usfirst.org/who/content.aspx?id=46

Melchior, A., Cohen, F., Cutter, T., & Leavitt, T. (2005). More than robots: An Evaluation of the FIRST Robotics Competition participant and institutional impacts. Waltham, MA: Center for Youth and Communities, Brandeis University. Retrieved March 16, 2009 from http://www.usfirst.org/who/content.aspx?id=46

Rogers, K. B. (2007). Lessons learned about educating the gifted and talented: A synthesis of the research on educational practice. *Gifted Child Quarterly, 51*(4), 382-396.

US FIRST. (2008). Who we are. Retrieved on October 1, 2008 from http://www.usfirst.org/who/default.aspx?id=34

US FIRST. (2008). FIRST At-A-Glance. Retrieved on October 1, 2008 from http://www.usfirst.org/who/content.aspx?id=160

Waks, S., & Merdler, M. (2003). Creative thinking of practical engineering students during a design project. *Research in Science & Technological Education, 21*(1), 101-121.

Websites of Interest

http://www.usfirst.org

http://www.firstlegoleague.org

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