LAWRENCE TECHNOLOGICAL UNIVERSITY

Arts and Sciences College

Natural Sciences Department

A Comparative Study of, and Methodologies to Improve the use of, Middle School Robotics Competitions for STEM Education.

A thesis presented in partial fulfillment of the requirements for the degree of

Masters of Educational Technology

by

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Abstract

During the past 15 years the number of robotics competitions geared towards middle school students has risen dramatically. Not only has the popularity of these types of competitions increased, but the quality and sophistication has risen as well. Coaching a successful youth robotics team does in fact require a great deal of time and commitment, but when done properly can prove to be one of the most rewarding experiences of a lifetime. In this dissertation we will examine several of the largest, most successful robotics programs in existence today. We will share experiences from successful teams and provide tips for creating a new team, or improving an existing team, and suggest possible improvements for future competitions. In addition we will also provide information about some of the more popular software titles and show several sample programs.

Acknowledgements

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And Finally, I would like to thank the Hamtramack Board of Education, all of it's administrators and board members, for all of their support throughout the years. Without their cooperation I would have never been able to experience the joys of coaching a robotics team.

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Chapter 1
Introduction to the Study

In this paper we will discuss some of the more popular robotics competitions currently available to middle school age students. We will provide a brief history of each and explain the materials required and expenses a team can expect to encounter. Following that we will provide some helpful tips for starting a robotics team and explain how you as a coach can incorporate science and math into the learning processes of your robotics program. Next we will share some of our experiences with two of the more popular robotics competitions, FIRST Lego League (FLL) and Robofest. We will also explore some of the more popular software titles available for programming robots and share some sample programs. And finally, we will discuss and make suggestions for possible improvements to future competitions.

Statement of the Problem

There are many robotics competitions in existence today and choosing the right competition for you and your students can sometimes be a difficult task. Most all the current popular competitions claim that one of their goals is to help improve STEM (Science, Technology, Engineering and Mathematics) education through the use of robotics. Although most of these programs do an adequate with the implementation of Science, Technology and Engineering, very few are actually addressing or implementing true Mathematics concepts.

Purpose of the Study

When it comes to choosing a robotics competition for middle school age students there are many programs out there to choose from. The task can sometimes seem overwhelming at times. Which program is the best choice for you and your team? That is one of the purposes of this paper. We will try to provide you with the information needed to help make the decision a little easier. Some of these competitions can be very expensive to enter, but with the proper information perhaps you can avoid unnecessary spending and disappointment for both you and your team.

Starting a robotics team can sometimes be a daunting task. There are many decisions that you as a coach are going to face. How many students should you have on your team? What type of software should you use for programming your robot? These are just some of the types of questions that we will try to help you answer and make the decision making process a little easier for you as a coach.

In addition to helping coaches make some of the difficult decisions they may encounter starting a robotics team, we will also attempt to help both coaches, as well as competition organizers, incorporate the use of science and mathematics into their programs to help make the STEM experience more rewarding for the students, and inadvertently helping to improve STEM education in general through robotics competitions.

Chapter 2
Current Middle School Robotics Competitions

FIRST Lego League

History

FIRST (For Inspiration and Recognition in Science and Technology) Lego League (FLL) was founded in 1998 by inventor Dean Kamen. It was designed to act as a feeder program for the popular High School robotics program FIRST Robotics Competition (FRC). FLL is geared toward 9-14 year-old students and uses the Lego Mindstorms kits. Since it's pilot year in 1998 it has grown from 210 teams in two countries, to over 14,725 in 56 countries in the 2010 season (FLL website).

FLL uses challenges based on real world scientific problems to engage children in research, problem solving, and engineering. The heart of the program is its core values which emphasize friendly sportsmanship, learning, and community involvement, with gracious professionalism being stressed the most.

Each yearly Challenge has two parts, the Project and the Robot Game. Working in teams of three to ten children and guided by at least one adult coach, teams have 8 weeks to build an autonomous robot to carry out predesigned missions in 2 minutes and 30 seconds and to analyze, research, and invent a solution to a real world problem. (FLL Website)

Cost & Materials

The costs for participating in a FLL competition vary depending on whether your team has a Lego Mindstorms kit. The registration fee for the 2010 season, which is required for all team that wish to participate, is $200. If teams chose to purchase a field setup kit, which is highly recommended, the cost is an additional $65. This is for the pieces to build the mission models and the field mat, but not the playing field itself. The field itself can be constructed using a 4' X 8' sheet of plywood or other material, three eight foot two by fours and 20 or so wood screws. These items can be purchased at most building supply stores such as Home Depot or Lowes for less than $50 and the same field can be used year after year. This will allow your team the ability to practice on an actually playing field just like the ones that will be at the competitions. It would be really hard to imagine a team having a successful season without a field setup kit, but it is not required that a team purchase one. Some people may wonder why FLL does not require a field setup kit, or why they don't just include it in the registration fee, the reason being that some schools have two or more teams and they choose to share the field setup kit. If your team is new to FLL and you do not have a Mindstorms kit FLL offer teams an opportunity to purchase an Educational kit, resource kit with extra pieces and the latest educational version of the NXT-G software for an additional $395. So, as you can see, the cost for registering a team range from a minimum of $200, if your team has a kit and you choose not to purchase a field setup kit, up to $660 if you are new to FLL and do not have a Mindstorms kit.

The FLL playing field from 2008

Another thing that you should also realize is that these are probably not going to be the only cost that your team will encounter during the course of a season. Most regional qualifying competitions require an entry fee which is usually around $40, and then if you team is fortunate enough to qualify for the State competition you would be looking at about another $40 entry fee. Although they are not required, it is a good idea to have matching shirts for your team. The cost for shirts can vary as well, depending on what you decide will work best for your team. Some teams just buy T-shirts and then use iron-on transfers or fabric paint, while others choose to have a professional graphics company do the work for them. Whichever you choose to do is fine, but for the sake of the kids, so as to avoid making them feel different, or excluded from the other teams, I would highly recommend matching shirts for the team, including the coaches and mentors. One final cost to consider is that of trinket, or small gifts that have your team name and number on it. Again this too is something that is not required, but has become a traditional part of FLL. Some teams choose to use a simple piece of candy with a small label attached to it, while other teams have pens, Frisbees or bracelets made by professional graphics companies. Regardless, it is nice to have something for your team to pass out to other teams.

Our t-shirts for the 2008 FLL

So, if you are just starting a team for the first time you can begin with as little as $660 but you should realistically plan on spending more like $1000 if you include T-shirts, trinkets and regional registration fees. The cost for the following years will decrease by nearly $450 because you will already have your Mindstorm kit and your playing field.

For more information on starting a FLL team visit www.firstlegoleague.org/

Robofest

History

Robofest was founded in 2000 by Dr. CJ Chung, Associate Professor of Mathematics and Computer Science, at Lawrence Technological University (LTU). It is geared towards students in grades 5th through 12th. In its first year 109 students participated at one site, LTU. In 2009 over 1,763 students participated at 32 sites throughout the world (Robofest.net)

Robofest is an autonomous robotics competition that takes place each year in the spring. One thing that separates Robofest from other robotics competitions is the fact that it offers teams the option of participating in any one of several different categories. There are Junior and Senior age divisions in both the Game Competition and the Exhibition. There is also the L2Bot competition for High School and College students and RoboFashion and Dance Show for students in grades 5th through 8th.

For the Game Competition students build autonomous robots that are required to complete various tasks in an allotted period of time. In the Exhibition teams are allowed to show off their creativity by constructing any type of robotic device of their choosing. Teams are given complete freedom in this “anything goes” creative competition of the minds. The rules are simple, as long it is safe and not human controlled, teams are encouraged to let their imaginations go wild. The L2Bot challenge is a vision-centric competition for both talented high school, and college students as well. In this competition teams use computer vision as their main sensory modality of autonomous mobile robotics to design a robot to navigate its way though a mock urban setting using 2D barcodes placed on the floor by judges (Robofest, 2010). In the

RoboFashion and Dance Show teams use two plastic 30” x 72” tables to create a stage and are free to use their imaginations to design dance routine or skit in which their robots perform. The Fashion and Dance Show is designed for students between grades 5th through 8th. Teams have up to two minutes to impress the judges with their costumes, dance motions and use of sensors.

Cost & Materials

This is one of the major advantages that Robofest has over many of the other current robotics competitions. Robofest is one of, if not the most, affordable competitions a team can enter. Last year, the 2010 season, it cost only $50 to register a team for any one of the above mention events. The cost for the playing field is not only affordable, but very simple to create as well. Both the RoboFashion and Dance Show and the Junior and Senior game are played on a plastic folding table which can be purchased at a variety of stores for approximately $70 to $100, depending on the brand. Once your team has purchased the table, or tables, they can be used year after year.

As for the robotics kits themselves, teams are free to use any robotics kit they choose. As mentioned earlier a Lego Mindstorms kit (one of the more popular choices among teams these days) can be purchased through Lego Educational (http://www.legoeducation.us/store/) for $280 and the NXT-G software can be purchase for $80. As with FLL, and most other popular competitions, Robofest does have an entry fee for qualifying competitions which on average cost about $40 for the local, or regional, and another $40 if your team is lucky enough to qualify for the World Championship.

In addition to the above mentioned cost you should expect some other minor costs as well. You will probably want to consider either purchasing or making shirts for your team, although it is not as much common place as it is in FLL. Trinkets are also not as common at Robofest competitions, but they are still appreciated by most spectators and members of the other teams.

So, as you can see starting a Robofest team is quite affordable compared to other competitions. Depending on the category that your team decides to enter you may have some other cost for creating a playing field, but for the most part these additional things are common household items that can usually be acquired for $10 to $20. For example in the Fashion & Dance Show this past year our team spent about $20 on materials to make the costumes for our two robots. With your registration fee, a plastic folding table, Mindstorms kit the startup cost for a teams first year are just under $500, but because you will now have the table and kit, in the years to follow you can expect to spend about $120 for registration fees and T-shirts.

If you are interested in starting a Robofest team of your own, or would like more info visit http://www.robofest.net/

BEST

History

Founded in 1993 by Ted Mahler and Steve Marum, engineers at Texas Instruments, BEST (Boosting Engineering, Science, and Technology) is a non profit, volunteer-based organization headquartered out of Auburn University. BEST began its first competition with 14 schools with a total of 221 students taking part. Today BEST has over 700 middle and high schools with over 10,000 students participating each year. The competition consists of two parts, a robotics game which is based on an annual theme, much like FLL, and the second part which is the BEST Award which is given to the team that best embodies the concept of BEST which includes a project summary notebook, oral presentation, table display and sportsmanship.

Each team is provided with a kit containing equipment and various parts and a set of rules. Teams are then given six weeks to design, build and test a robot to compete against each other.

Cost & Materials

Teams that participate in BEST are not required to pay any costs, but it is expected that teams help with various fundraising activities for their regional hub. Interested teams must first apply with the regional hub, if no hub exists in your area you must then try to form a hub in your region. Forming a hub however is no easy task. BEST Robotics licenses use of it’s annual competition to companies, colleges, universities, professional engineering societies or groups of individuals interested in starting a competition in their community. Licensees must then pay $2000 per year to BEST Robotics Inc. Each hub is self sufficient and it’s organizers must raise their own funds and supply their own volunteer workforce to help run the competition. Before permission can be granted to form a new hub a license must be granted and the organization must first get approval form the Board of Directors. Currently at this time there are no hubs in Michigan. Anyone interested in forming a hub or if you would like more information about BEST visit http://best.eng.auburn.edu/

Botball

History

Founded in 1997 by the KISS (Keep It Simple Stupid) Institute for Practical Robotics (KIPR) the competition is geared towards middle school and high school age students. Each team that registers is provided with a kit that contains various components including sensors, motors and enough materials to build two complete robots. The Botball season is longer than most of the other popular competitions. The season begins in the fall when teams begin an optional Research and Design Website Challenge where teams are asked to research a topic in robotics and to develop a solution to a related design task. In January and February team leaders and mentors are given training and are introduced to the game and its rules for that year. Then teams are given about seven weeks to design, build and test their robots before the regional tournaments begin.

Cost & Materials

With a $2,500 registration fee Botball is one of the more expensive competitions. They do however offer a $200 discount for teams who register prior to September 30, and if a school or organization registers more than one team they receive an additional $200 incentive for each additional team. There is also the cost of the optional practice arena, which as with all other competitions, is also highly recommended. Unlike many of the other popular competitions the playing field, or arena as they refer to it as, changes each year so the exact cost is unknown until the game is revealed for that year. They claim however that the cost of constructing a practice arena is kept to a minimum, and that all of the materials can be purchased from most home improvement centers. One nice thing is that 10 T-shirts are included in the registration fee.

So, as you can see Botball requires a significant amount of money for registration, but they do offer teams some really neat fundraising options. If you are interested in forming a Botball team or would just like to learn more about Botball visit http://www.botball.org/

Chapter 3
Suggestions for Creating a Robotics Team

Team Dynamics

Team Size

One of the first decisions that you will have to make is the size of your team. The first thing you need to check is whether or not there is a size limit for the competition that you are planning to enter. For example, FIRST has a limit of ten students per team. Robofest on the other hand, recommends that teams not exceed seven. Because of the fact that Robofest does not require a team research project you may not have enough roles for that many students, it is recommended that team sizes be slightly smaller, depending on the event you choose to participate in. Some coaches feel that a larger team is more advantageous because the work can be divided more easily using subgroups to work on separate tasks. Limiting team size can sometimes lead to some difficult decisions for you as a coach. Often times you will have more kids that want to participate than completion regulations allow. This is the same type of dilemma faced by coaches of other team sports, or clubs. Who should make the team, and who should be cut? How you decide to chose is ultimately your call, but regardless of the method you chose to use, you are going to have some kids who are upset. If this does become an issue, and you don’t have either the resources, or enough participants, to form another team, there are still some things that you can consider to allow those other that cannot be on the actual team to still participate, and at the same time contribute to the success of the team. I have always tried to allow the older kids an opportunity to participate on the actual team for the simple fact that they may not have the opportunity to participate in future competitions because of age restrictions that are set by some of the various robotics organizations. One drawback of this though can be the fact that if you do allow the team to be made up entirely of older kids, you may find yourself with a whole group of inexperienced students the following year. You may want to consider trying to find a nice balance of both younger and older kids, or at least three younger kids that can provide experience for the next season. In the past I have found it beneficial to allow the students that have not been selected for the team to help with other activities such spirit committee or fundraising. I usually will tell that that if they participate on a regular basis and do a good job, that they will have a much better chance of being selected for the next year's team because of the valuable experience that they will have gained this year. This will provide them with an opportunity to still feel part of the team, gain experience and help increase the team's chances for success.

Age Variations

This can also prove to be another difficult decision for coaches as well. As most adult know, there tends to be a very distinct developmental difference between nine year olds and 14 year olds. This age difference can sometimes pose problems with gender-based cliques. Some coaches prefer to form two separate teams if possible, one for the older kids and one for the younger ones. This can help alleviate some of the clique issues, but on the other hand the success of the younger team can sometimes be compromised. This may not always be the best solution. Often times the younger students can learn from the older ones and this in turn can be beneficial for future team development. Consider pairing older kids with younger in various roles such as builder, programmer or operator (the concept of roles will be discussed more later in this section). This will often times help prepare and teach the younger ones for future competitions. Whichever method you choose, whether it be to separate by age, or pair them up, just realize that there is a developmental difference and that you should take the necessary steps to avoid the separation and the older ones doing most of the important work and the younger ones being excluded.

Time Commitment

How often, and for how long should your team meet? This is a question that you as a coach are going to have to decide. The obvious train of thought would typically be, the more the better, but there is a little more to it than that. One thing that you need to keep in mind is the fact that many students who are going to express interest in joining your team are going to be the same kids who make up Student Council, National Junior Honor Society, the school band and many of the schools other after school programs. It has been my experience from the past that many of my best team members are some of the most active kids in the school. Yes, it is true that children do need to decide which activities are most important to them, and that they cannot spread themselves too thin by participating in too many activities, but on the other hand you do want to avoid losing some of the best and brightest students in the school because they are part of other organizations. First, try to meet with the leaders of the other after school groups and find out what days they are planning to hold their meetings, perhaps you can then try to schedule your meetings on the off days. You probably won't be able to work around all of the different schedules, and no matter how hard you try you're not going to be able to accommodate everyone, but at least by trying you may avoid losing some really good members to other groups or organizations.

So, how many times per week should you meet? Most coaches agree that teams should meet for a minimum of two days per week, at least for the first couple of months, but as the competition draws near you may find it necessary to increase the number of meetings. In the past we have usually found ourselves wanting to meet each day the final week before the competition.

As for the amount of time allotted per meeting, over 70% of team members surveyed felt that four hours per week was not enough time to prepare for a competition. So, depending on the number of days you decide to meet you should count on at least a minimum of two hours per meeting. Another thing to consider is the amount of time that it takes to setup and cleanup each meeting. Unless you have the luxury of being able to leave all of your materials out and in place and can just leave things as they are until the next meeting, cleanup and setup are going to consume a considerable amount of your meeting time. Anything less than an hour and a half and you may find it difficult for the meeting to be productive.

In summary, three days per week seems to be an ideal starting point, with meetings lasting two hours if possible. You may decide that more time is needed, especially if the majority of the team is inexperienced, or has never competed in a competition before. Just keep in mind that many of your team members may have other commitments.

Roles & Responsibilities

One thing that most coaches and team members can agree on is that assigning specific roles to each team member is one of the keys to a successful season. Over 90% of the team members surveyed said that they felt that it was very important for members to have a specific role. Depending on the type of competition you are planning to enter the roles may be slightly different from those mentioned here. For example, in preparing for this past years FIRST competition we had assigned the following roles or sub-teams;

Builders-It is the builder's job to work on the actual design and construction of the robot itself. The builders also look for input from other team members and must work in conjunction with the programmers.

Programmers- The programmers work almost hand in hand with the builders to design programs based on the requests of the builder's design and construction methods.

Researchers- It is the job of the researchers to investigate the challenge theme for the season and chose several possible project ideas to present to the team for selection. Once a project has been selected they then work hand in hand with the presenters to come up with a viable solution for the project...

Presenters- This is the group that will prepare and present the final project and solution to the judges at the actual competition. It is their job to design creative ways to present the material and then share those ideas with the team.

Operators- It is their job to handle and operate the robot during the tournament. They work closely with the builders and programmers to try to come up with ways to save time and make the robot run more efficiently.

This type of configuration works nicely for a ten person team, with two people making up each subgroup. For Robofest you may not need all of the mentioned subgroups depending on which event your team chooses to partake in. For example if you were going to enter the RoboFashion and Dance Show you might want to replace the presenters and researchers with a design team.

You may even find that some members want to be involved with more than one subgroup. This may work, but just try to ensure that everyone is participating equally. There are also some smaller roles that your team may or may not find necessary. These roles are sometimes helpful when you have more than the allotted number of kids wanting to participate.

Spirit Committee-They try to think of ways that the team, family members and friends can show support for the team by making T-shirts, buttons, hat etc.

Fundraising- It is there job to come up with ways to raise money for the team. Bake sales, T-shirt sales, candy sales are just a few of the many ideas.

Even though it is the job of the sub-teams to come up with the main ideas for their group remember that ultimately the final decision should involve input from all team members...

Incorporating Science

It is one thing to teach the students how to use the various sensors, but more importantly we as coaches should make it a point to ensure that we are also teaching the kids *how* the sensors work as well. If the students can acquire a firm understanding of how the sensors work they will be likely to use the sensors to their fullest potential.

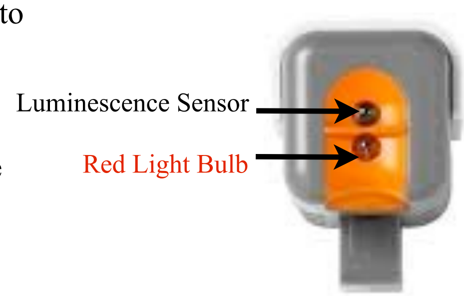
In this section I will share with you some of the techniques that I have used in the past to teach the kids about the basic operations of the more popular Mindstorm sensors by relating them to things that the kids already have knowledge about.

Ultrasonic Sensor

The ultrasonic sensor work much the same way that sonar works, or the way that bats are able to find food and navigate their way through the night sky. The sensor sends out a high frequency sound wave and then measures the amount of time it takes for the wave to bounce off of the object and then return. After explaining this to the students you can then show them the simple formula for speed (Speed = Distance / Time). For example if a car is traveling 40 miles per hour (mph) the per hour is just another way of saying “divided by”. So if you then show the kids a simple math problem like 4 = 8 / 2 you can then explain that if we know any two parts of the equation we can figure out what the missing number would be. In this case if we know the speed of the wave (which the NXT knows) that is the “S” in our equation, and if we know the time it take for the wave to travel and come back, the “T” (the NXT uses built-in timers to measure this and then divides it by two, the time to go out and come back) it can then figure out the distance “D” that an object is away.

Light Sensor

Just as we did with the ultrasonic sensor we want to try to relate the light sensor to things that the kids already know about. If you were to ask students what color clothes do most people wear in the summer, or ask them about the popular fashion rule about wearing white pants or dresses, some will know about the old fashion fapoe that you are not supposed to wear white before Memorial Day. Or if they happen to be from certain ethnic backgrounds they may know that in many cultures people wear different colored clothing during the various seasons. For example, some of the kids on our team are from Yemen and they know that in back home during the summer months people wear light colored clothes in the summer and darker colored clothes in the cooler winter months. Although some of them may not know exactly why this is, I explain to them that the dark colored clothes absorb the sunlight, helping to warm the body, and the light clothing reflect the sunlight helping to cool the body. Now you can explain to the kids that the light sensor works the same way. Show them that there are what appears to be two small bulbs on the light sensor. Only one of these, the red one, is actually a bulb, the other is a luminescence sensor that measures the amount of light present. The red bulb shines light onto the surface, and depending on the color of the

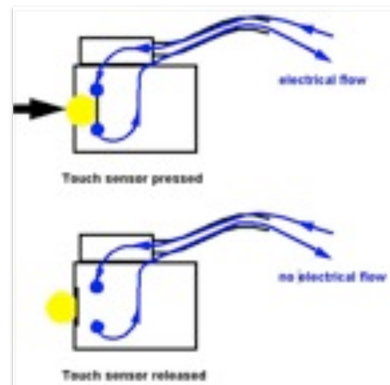


The NXT Light Sensor

surface the light will either be absorbed if it's dark in color or reflected if it is light in color. The luminescence sensor will then determine how much light is being reflected back and then convert this reading into a number between the 0 and 100, with 0 being an extremely dark surface and 100 being a really light surface.

Touch Sensor

The touch sensor is really nothing more than a common micro switch. These micro switches are very common in our everyday lives. Ask the kids if the light inside of their refrigerator stays on all of the time, or how does the light in the car come on when you open the door? Explain that there is a micro switch, and depending on how the switch is designed, that the electrical circuit is completed when the button on the switch is either pushed in or released.



How the Touch Sensor works

Incorporating Math into Robotics

Because of the various sensors, the incorporation of science in robotics is a relatively easy thing to do, but the incorporation of math into the robotics portion of STEM education on the other hand is not such an easy task. Teaching math concepts is not always as obvious as the science concepts. Yes, there is the circumference of the wheels, and if you're using the rotation sensor you can have the kids figure out the distance traveled with each rotation of the wheel. There is also the speed equation that we discussed in the section on the ultrasonic sensor, but other than these and a few other instances, the incorporation of math is somewhat limited in most current robotics competitions. This is one of the issues that Dr. Chung and the organizers of Robofest are aware of and are trying to address in it's future competitions.

One thing that you as a coach could do to help incorporate math into your program is to have the kids figure out the distance traveled in one rotation of the wheel by calculating the circumference of the wheel on the robot, and then comparing that to value shown using the view button (a common method used to determine the value needed to travel a certain distance).

As we will discuss in the Conclusion, this is one of the areas of robotics competitions that needs improvement. There is not enough inclusion of math, some organizers, like Dr. CJ Chung, with Robofest are aware of this problem and due plan to address the issue in future competitions

Chapter 4
Case Studies

Experiences with FIRST

Our team has participated in FIRST Lego League (FLL) since it began here in Michigan back in 1999. A lot has changed since that time. The first couple of years were a learning experience for all. The first year the challenge was called First Contact and the theme for that year was Space. There was no project back then, although some might argue that just making one of the playing fields was a project in and of itself. That year the field objects were constructed out of wood and plexiglass and each team was given a set of instructions and a list of materials needed. It was up to each team to go and purchase, cut and put together all of the materials to build their own playing field. As a team we spent over forty hours just creating the playing field.

The following year was even worse; the playing field was so complicated that many teams from the previous year didn't even compete because they weren't able to get the field constructed. This caused FLL to take a closer look at the construction of the playing field and the competition itself. 2001 saw the introduction of the playing field mat. Teams would no longer be required to mark the playing field with electrical tape. Now the lines and markings for the placement of the mission objects were printed on a vinyl mat and the mission objects themselves were now constructed out of Lego pieces. All of these materials were sent to the team as part of the registration process. These changes shifted much of the work from the coaches to the teams themselves.

As for the robots themselves, they were not very impressive compared to today's standards. For First Contact our team didn't use a single sensor, all of the programs relied on the internal timer, that was all we could figure out how to use in the limited amount of time we had left after the nightmarish construction of the playing field. In fact, the rotation sensor didn't even exist at that time, so needless to say most of the robots were very crude and somewhat simplistic to say the least. It didn't take us long to figure out that the use of timing to have the robot travel a given distance was not a very efficient method. The main problem was the fact that as the battery strength weakened the distance traveled shortened and because of this it was very difficult to construct accurate robots.

Over time there have been several major achievements that we have accomplished. Here we will discuss some of these discoveries that have help lead to the success that we have had in the past seven years or so.

The Rotation Sensor

In 2000 FLL provided each team with a rotation sensor, but most teams including ourselves were not able to get it to work properly using the RIS software that came with the Mindstorms sets. Then, in 2001 teams were provided with a Bata version of Robolab a new software platform for Lego Mindstorms kits. With Robolab our team was finally able to figure out how to use the rotational sensor. The addition of the rotation sensor was the actual beginning of our success in FLL. Since then we have learned how to use the rotation sensor to help us travel very precise distances, and we have also incorporated one into the arm on our robot. With the introduction of the NXT the new motors have a rotation sensor built in, and there is no longer a need to reset the rotation sensor each time you use it, making it much easy to use, and much more accurate as well.

Worm Gear

Another key to some of our successes has been the discovery of the worm gear; particularly it's usefulness in constructing the arm portion of the robot. For years we tried to construct a simple arm by attaching beams to a motor. If we wanted to lift an object we would turn the motor on and leave it on, or start with the arm in the up position and then turn the motor on to set the object down. The problem with this is that there is no in-between; the arm is

The worm gear is in the blue housing

either all of the way up, or all of the way down. By using an arm with a worm gear you are able to start the motor at whatever position you want and stop it wherever you want. This makes for a much more useful arm. Then if you add a touch sensor at the top of the arms rotation you can assure that the arm will return to the same starting point each time it returns to the top. Now if add a rotation sensor, or use the built-in one in the NXT motor you can dramatically in crease the accuracy of the arm.

String Programs

One disadvantage that the NXT has over the RCX is the button configuration. Many students have a more difficult time navigating their way through the NXT menu compared to the RCX menu. With the RCX there were only four buttons; the red power button, the black view button, the green run button, and the gray program button. This was very simple for the kids to use especially in a competition when the pressure was on and time was of the essence. The RCX can hold up to five separate programs, and to change programs you simply pressed the gray button to scroll through the programs. Navigation of the NXT is much more difficult, there are many more options on the menu, and one wrong press of a button can often times open a part of the menu that is unfamiliar to the kids. This can be very disastrous in a timed competition. To help alleviate these type of problems when using the NXT we came up with what we refer to as String Programming. By using a touch sensor to start each section of the program, or each mission if you will, we are able to combine all of the separate programs into one long program, and after the robot comes back to base and we have realigned it and added any new attachments we simply press the touch sensor to send the robot out for the next mission. Another variation of this same idea is to use the orange arrow buttons instead of the touch sensor; this may come in handy if there are situations in which the operators are accidentally pressing the touch sensor before they are ready to send the robot. This is one disadvantage of string programming, if a button is accidentally pressed you must start the program over from the beginning. There are ways to help eliminate this as well, one would be to write separate programs that contain only the code for the remainder of the program from various point throughout the program, but this can be somewhat time consuming. (See Appendix 2)

Battery Levels

One thing that many teams fail to take into consideration when designing and programming robots is the battery power level and the way the robot moves at various battery strengths. Even though the rotation sensor will make the robot travel the same distance regardless of battery strength there is still the issue of inertia to deal with. If battery levels are high the robot will move at a fast rate, or have more acceleration, which in turn will lead to a greater amount of momentum. This is especially important when the robot is performing turns. If the battery is fully charged the robot will make a very sharp hard turn and because of momentum it will tend to turn slightly further than what you may have experienced when battery levels were low. Often times teams will think that they have the program just right and then after several practice runs they will find that the robot is slightly off so they will make changes to the program, but then when they recharge the battery they find that the robot is now off again. As a team we have found it beneficial when building and practicing with the robot to consistently monitor the battery level and regularly charge the battery for several minutes to keep the level at consistent rate. All of this is really only practical if you use rechargeable batteries or the rechargeable battery pack available from Lego Education. It is highly recommended that your team purchase one or two of the rechargeable battery packs, not only to be able to maintain consistent battery levels, but it will end up saving a considerable about of money in the long run.

Sturdy Handle

An example of a sturdy handle

One thing that you will find out rather quickly is the fact that your teams robot is going be handled quit often. There is something that you can do to help reduce the chances of the robot from falling apart is the addition of a good sturdy handle. This will not only help during a competition but also during the design process and practice as well. Too often during competitions right in the heat of battle I have seen teams robot falling apart or pieces being knocked off while the team is trying to grab the robot quickly or from a certain angle. A good handle attached to the NXT, RCX or the base of the robot will help eliminate the chances of the robot falling apart.

Experiences with RoboFest Fashion & Dance Show

2010 was the first time that our team competed in the RoboFashion & Dance Sow at RoboFest and it proved to be an entirely new experience for both myself and the team as well. One of the greatest differences that we noticed between RoboFest and FLL were the rules in general. For example, in FLL there are many rules and restrictions, as to the number of sensors and motors that can be used in the construction whereas in RoboFest there is no limit to the number used. Another major difference in the rules are the allowable materials, in FLL teams are only allowed to use official Lego pieces, no tape or glue or any other type of materials are prohibited, but in Robofest teams are allowed to use any materials that they would like. FLL also restricts the type of robotic kits and the software that team can use where RoboFest allows teams to use any type of kits or any type of software. We found this less restrictive environment a refreshing change; we were not use to this type of creative freedom. Finally we could think "out-side of the box", there were so many times during FLL competitions that the kids would say something to the effect, "If only we could use tape", or "I wish we could glue this". At first this new found freedom did take a bit of getting use to. Because we were now able to use whatever we wanted it allowed for a greater amount of design change which in-turn ended up consuming a great deal of our meeting time during the design process.

The first thing we did was assign roles and responsibilities. For the most part the girls assumed their same roles from the FLL season but because the Fashion Show does not require teams to present a project we changed the roles of researchers and presenters to fashion consultants and choreographers.

Once the team decided on a routine the separate sub-teams began working on their individual tasks. The programmers faced some of the biggest challenges though. In FLL the team had never used the ultrasonic sensor or Bluetooth communication, two things that would be necessary in order to perform the routine as the other sub-teams had decided on.

One of the biggest challenges the programmers faced was the synchronization of the two robots. The girls were able to use one of the tutorials found on the Educational version of the NXT-G software to figure out how to use the internal Bluetooth devises to allow the robots to communicate with each other. By doing so the girls were able to have one robot act as the master, or lead robot, while the other served as the slave, or follower, robot, this helped to ensure that one robot did not get to far ahead of the other robot so that they would stay synchronized throughout the routine.

The programmers were also able to use the tutorial on the ultrasonic sensor to learn how to help the robots find the whereabouts of each other while on the table. This allowed the girls to make the robots spin for a given number of rotations and then locate the other robot so that they would end up facing in other every time the turned. (See the sample program in Chapter 5)

So, in conclusion the girls found that there were some similarities between FLL and Robofest, there were also some big differences, some that proved to end up being true learning experiences for the entire team, including myself.

Chapter 5
Software and Programming

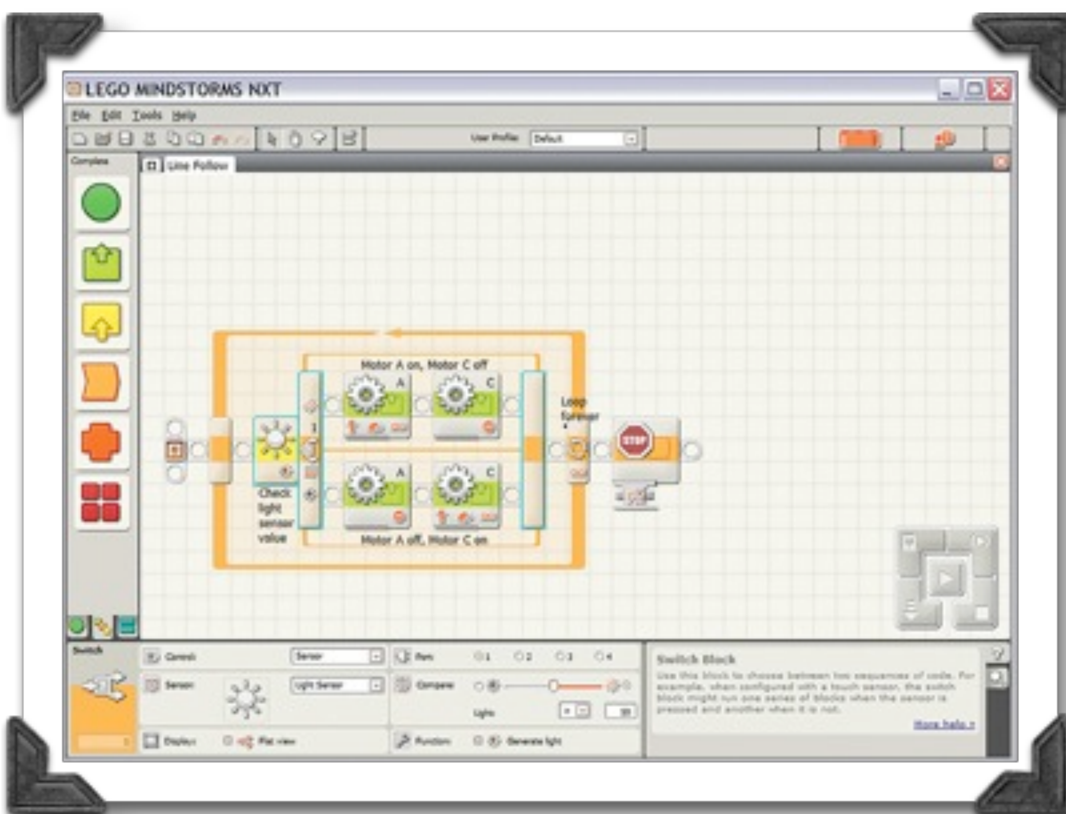
Types of Software

There are many different software programs currently available for teams to choose from. Listed below are some of the more popular titles currently being used in middle school robotics competitions.

Three different programming environments are available from LEGO for the NXT– NXT-G, ROBOLAB and ROBOTC, and they all make it quite easy to program Mindstorms robots. In addition, the open source community has developed other alternative programming solutions for the NXT. This section provides an introduction to the rich selection of programming approaches available today.

NXT-G

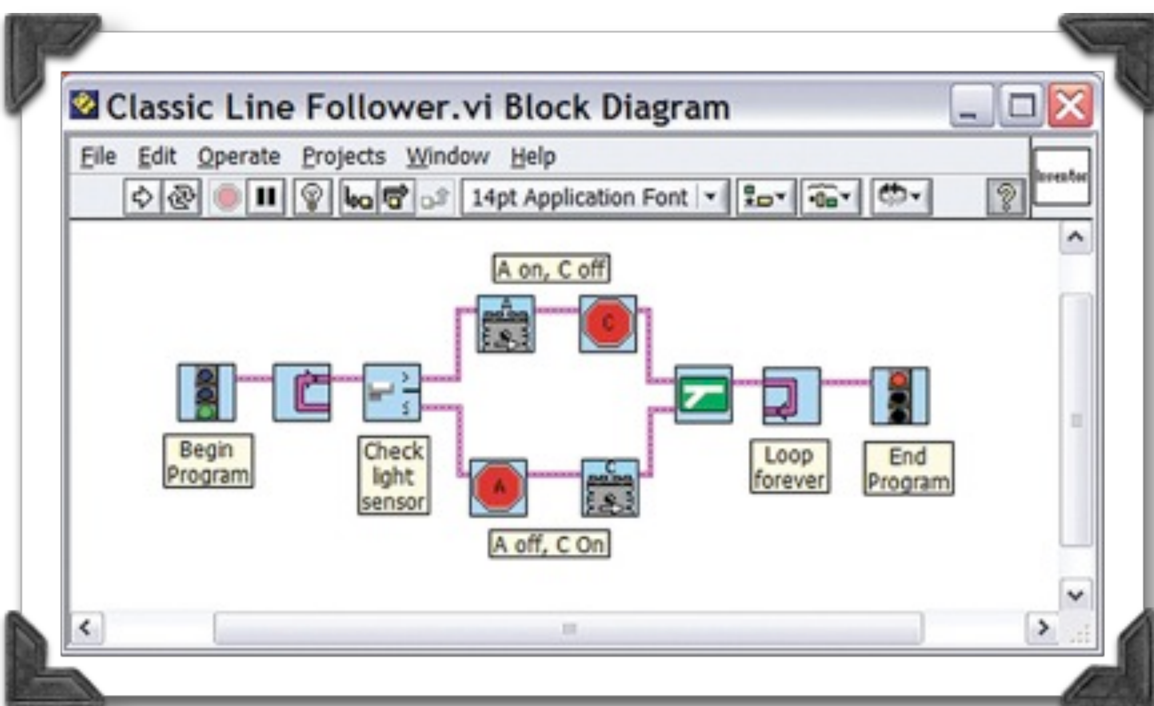
NXT-G is a graphical programming environment developed by National Instruments for LEGO. Writing an NXT-G program is very much like creating a flowchart. You “write” a program by dragging icons (“code blocks”) that describe different behaviors, e.g., turn motor A on at 75 percent of full power, and connect them with lines to describe the program behavior. Using a variety of code blocks, you can control motors, introduce delays, play sounds and direct the flow of your code according to the state of sensors and timers, etc. The diagram shows an NXT-G implementation for a “classical” line-following robot. The program looks at the value of a light sensor positioned above the line, and depending on which side of the line edge it is on,



i.e., light or dark, turns one rear wheel on and the other rear wheel off. This is implemented as a loop that is repeated forever. Inside the loop, the light-sensor value is checked and the program branches to “true” or “false” code based on the value. NXT-G is targeted at children and adults with no programming experience, and for this reason, it is very easy to use.

ROBOLAB

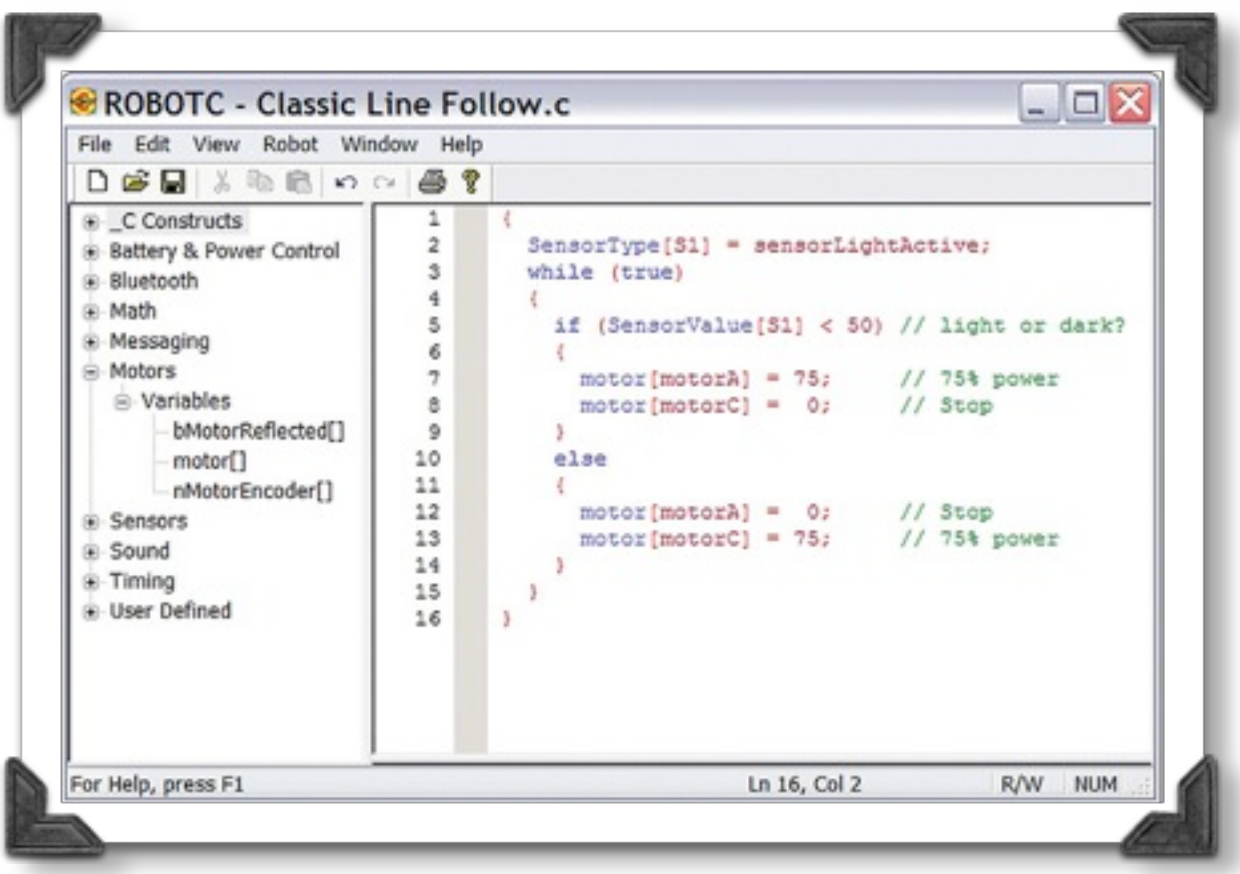
ROBOLAB was originally developed by Tufts University for LEGO for the first generation LEGO Mindstorms RCX microprocessor “brick.” It was extensively enhanced and revised to support both the RCX and the second-generation NXT. ROBOLAB is another graphical environment, although it is not as intuitive as the NXT-G language. If you already know ROBOLAB or you need to program both of the RCX and NXT, ROBOLAB is a good choice for you. If you’re just starting and want a graphical programming language for the NXT, the NXT-G is the better choice. ROBOLAB was written using the LabVIEW system from National Instruments. LabVIEW is also the underlying core technology used to write NXT-G.



Other useful ROBOLAB features include support of both integer and floating point calculations, and ROBOLAB has a comprehensive data-logging solution. Graphical interfaces such as NXT-G and ROBOLAB are very intuitive but can become tedious as you become more experienced with programming.

ROBOTC

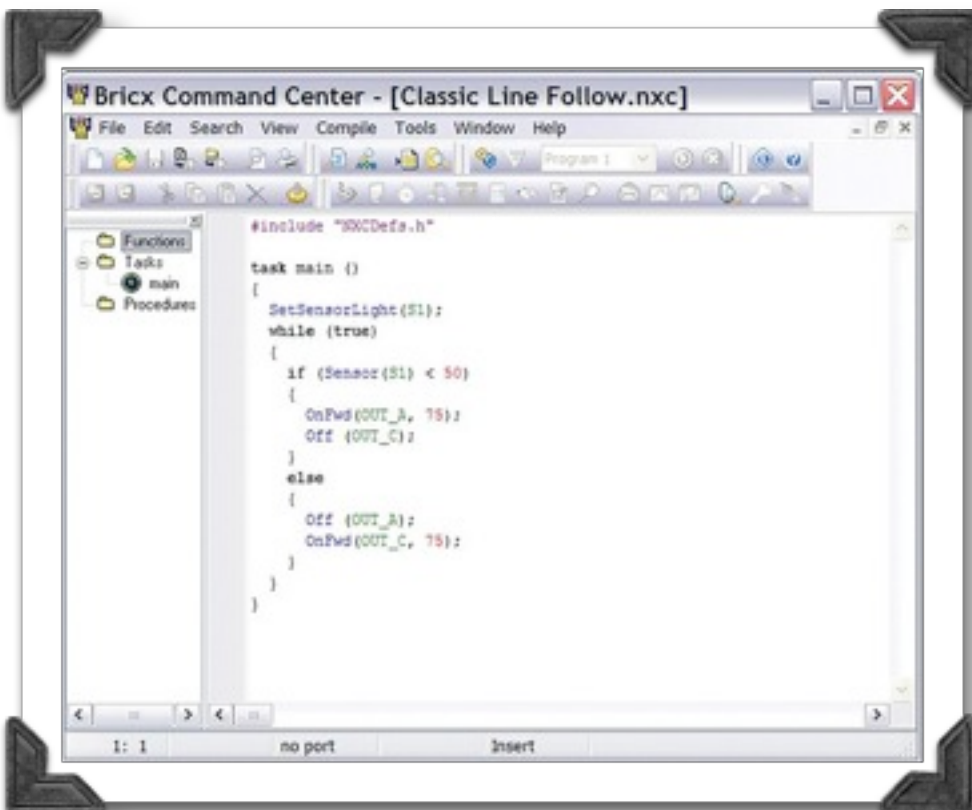
The ROBOTC solution allows the NXT to be programmed using the industry-standard C language. It was developed by the Robotics Academy at Carnegie Mellon University and can be obtained from the LEGO Education Group or directly from the Robotics Academy at www.robotc.net. Both of the graphical programming solutions had drag-and-drop capabilities for the "code blocks." ROBOTC has a similar capability, but with it, you drag and drop text. The left window in the picture contains the "dictionary" of ROBOTC's built-in robotics control



capabilities. ROBOTC is targeted at novices and advanced users. ROBOTC has "basic" and "expert" modes; in the "basic" mode, a lot of the advanced functionality and menus are hidden. ROBOTC has a powerful interactive real-time debugger that significantly reduces the time it takes to debug programs. So far, over 2,000 students have been taught ROBOTC in the classroom; at the end of the first class, they were programming and running their first ROBOTC programs for the NXT. Carnegie Mellon University's Robotics Academy has developed step-by-step instructional videos that enable new users to become competent programmers quickly. ROBOTC supports the NXT and RCX as well as products from Innovation FIRST (VEX and the FIRST Robotics Competition).

NXC ... NOT EXACTLY C

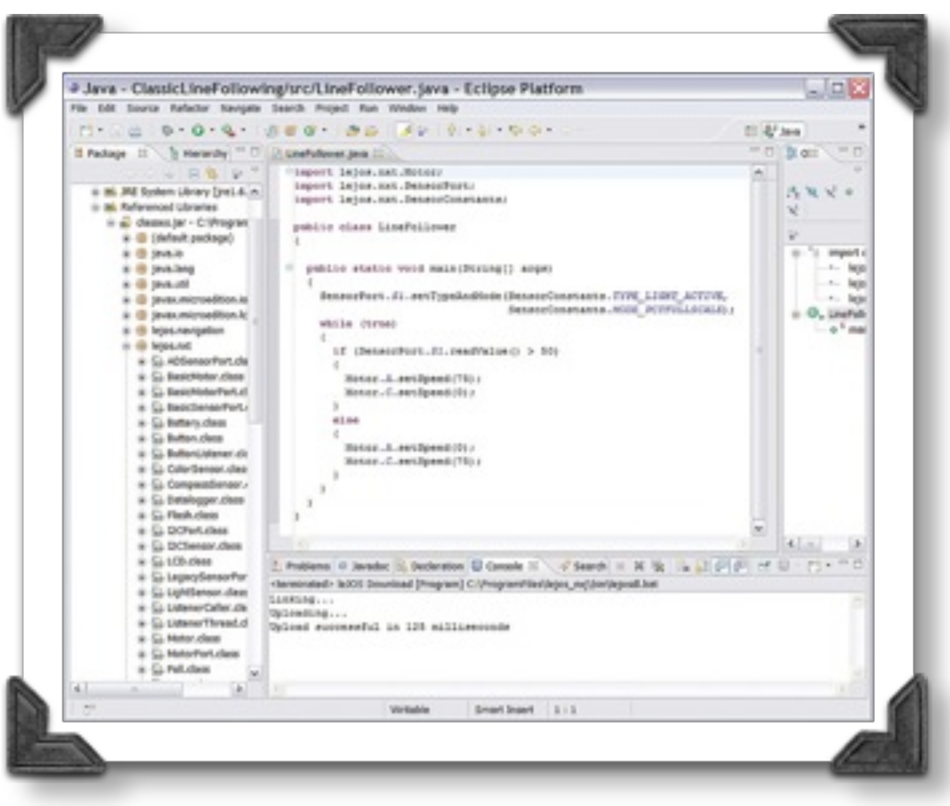
NXC (Not eXactly C) is a C-like language for the NXT. NXC programs are developed using the Bricx development environment. Bricx was originally developed for LEGO's earlier RCX robotics product and has been enhanced to support the NXT.



NXC uses the same firmware as NXT-G. This is very convenient for users who want to program in both a graphical and a text environment because they don't have to reload and change the firmware every time they switch the environment type. You can store both NXT-G and NXC programs simultaneously in the same brick. NXC has the same limitations as the NXT-G solution. It has integer but not floating-point variables. It doesn't have more powerful LCD text formatting. The NXC programming language syntax and semantics are similar to C's, but they are also different. For example, NXC character strings start with a double quote and end with a single quote; C uses double quotes for both the start and the end. NXC and ROBOTC are the only solutions that have run-time debuggers.

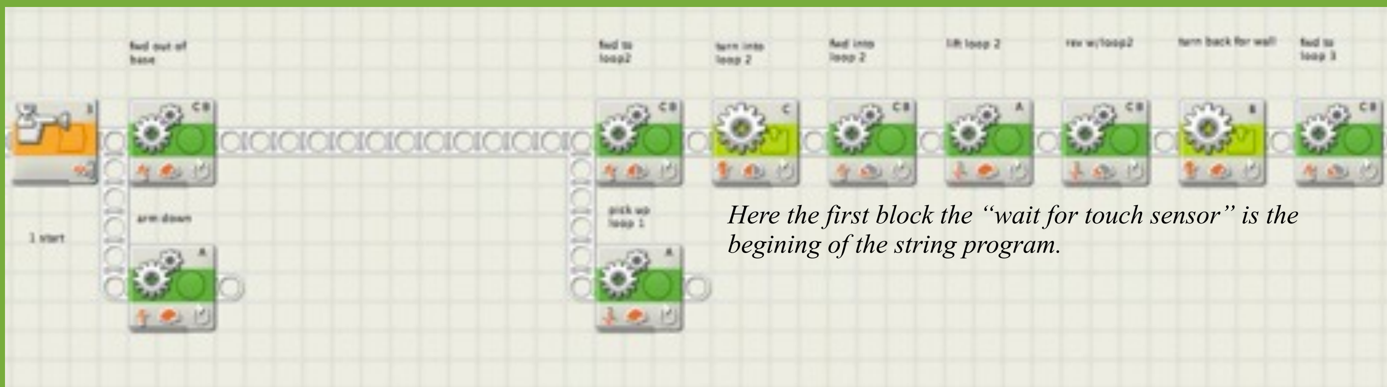
NXJ

NXJ is a JAVA implementation for the NXT. It is standard JAVA but with a much smaller Class library. The standard Class library is far too large for the total 256K bytes of memory on the NXT. NXJ programs are written and compiled on the PC. The compiled programs are then transferred to the NXT where they can be executed.

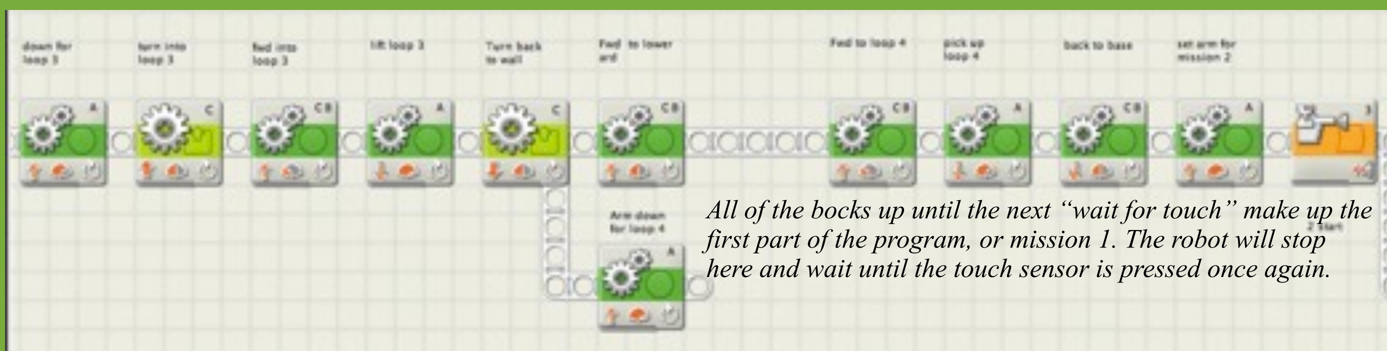


Sample Programs

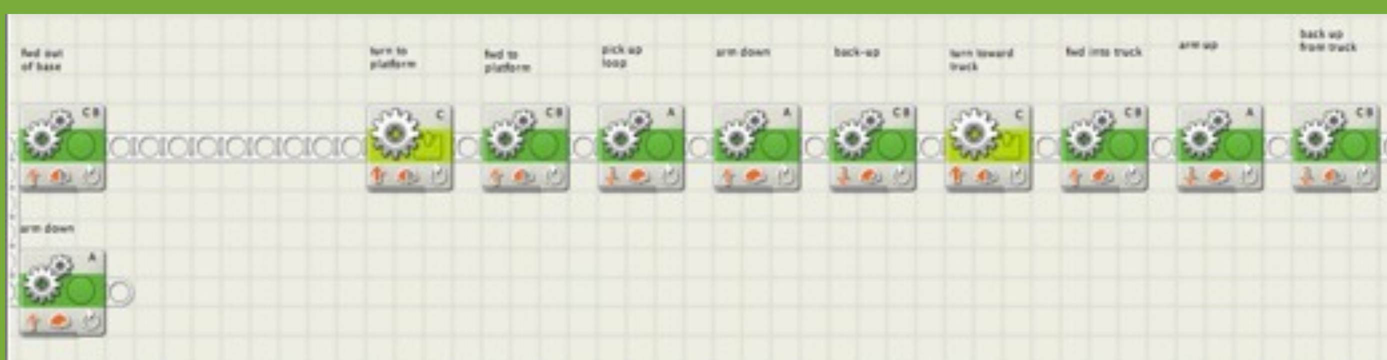
String Program (2009 FLL Program)



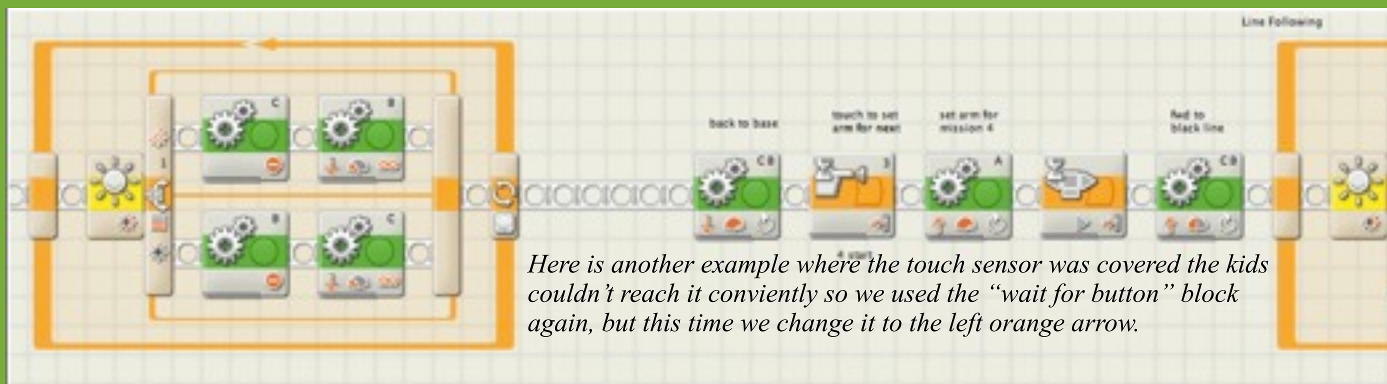
Here the first block the "wait for touch sensor" is the begining of the string program.



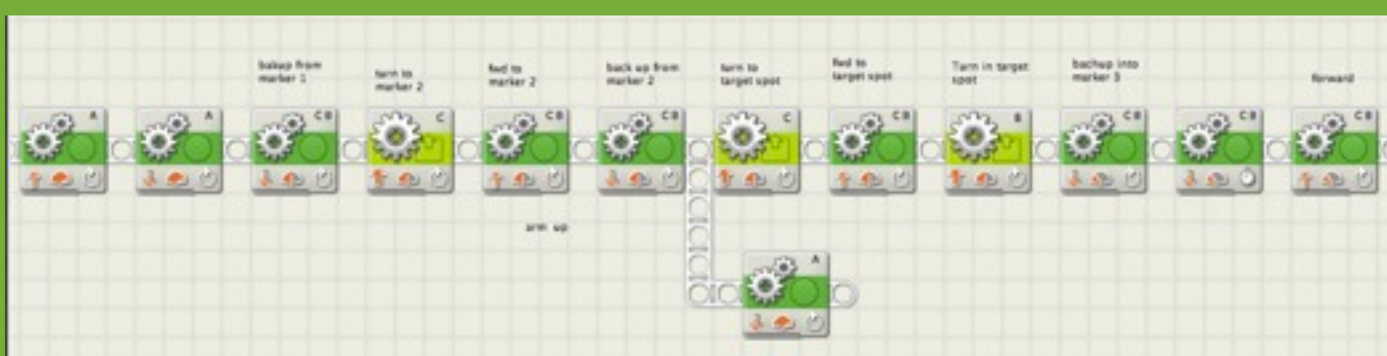
All of the bocks up until the next "wait for touch" make up the first part of the program, or mission 1. The robot will stop here and wait until the touch sensor is pressed once again.



Here the kids would sometimes accidentally press the touch sensor when they were adding an attachment so they used the "wait for button" block so instead of starting the next misson with the press of the touch sensor the robot waited until the orange right arrow button was pressed.

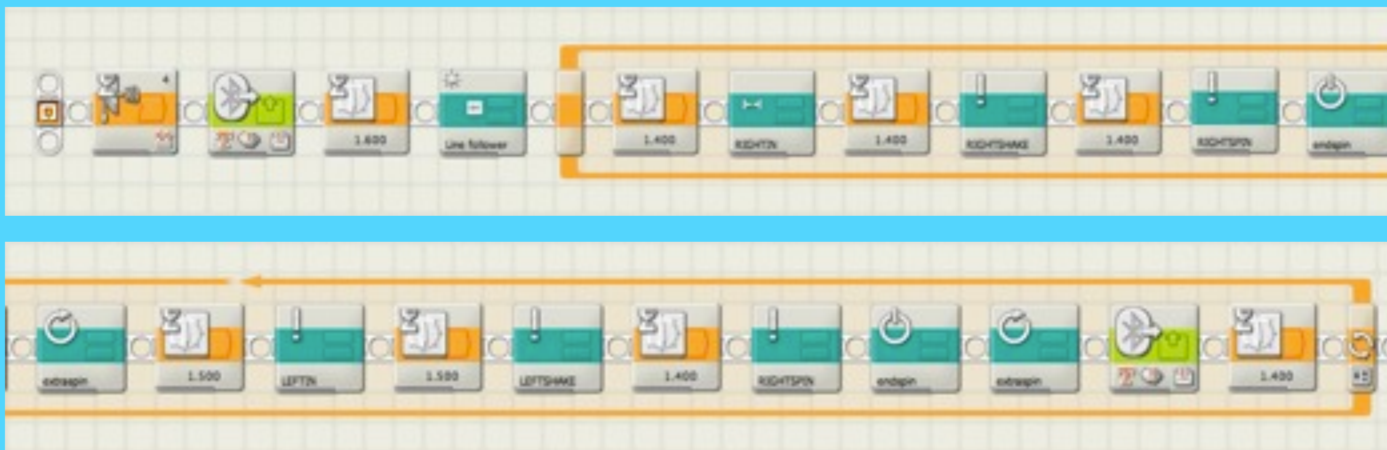


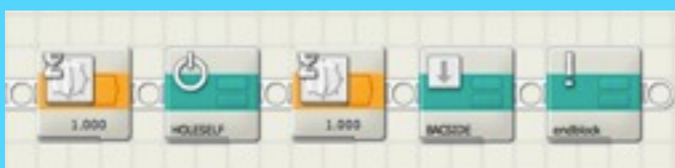
Here is another example where the touch sensor was covered the kids couldn't reach it conviently so we used the "wait for button" block again, but this time we change it to the left orange arrow.



RoboFasion & Dance Show Program

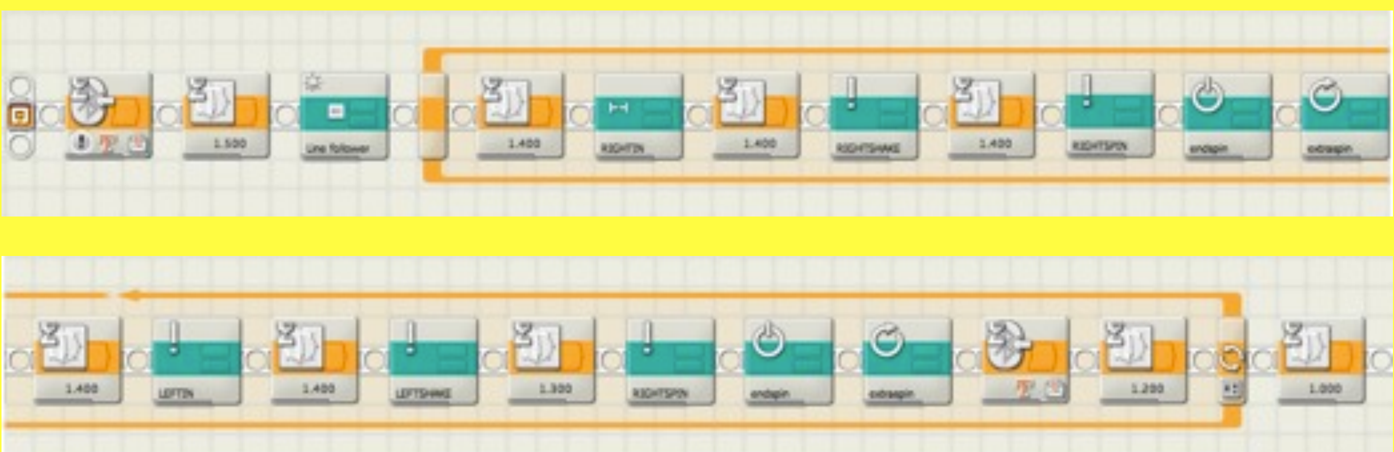
The “Master” Program





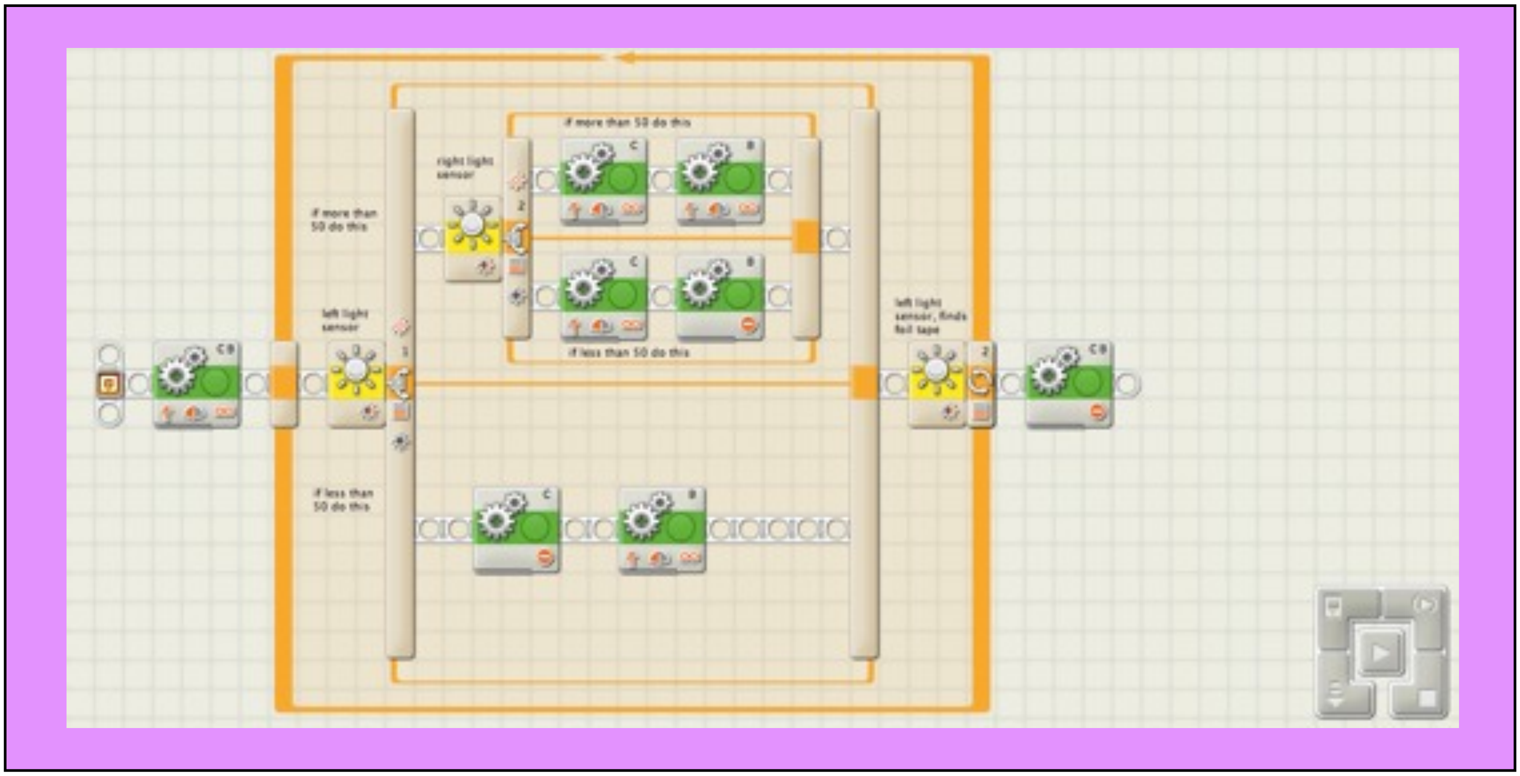
This is the program for the “Master” robot, the one that sent the BlueTooth messages to the “Slave” robot. Each of the “my Blocks” can be viewed after the “slave” program

The “Slave” Program

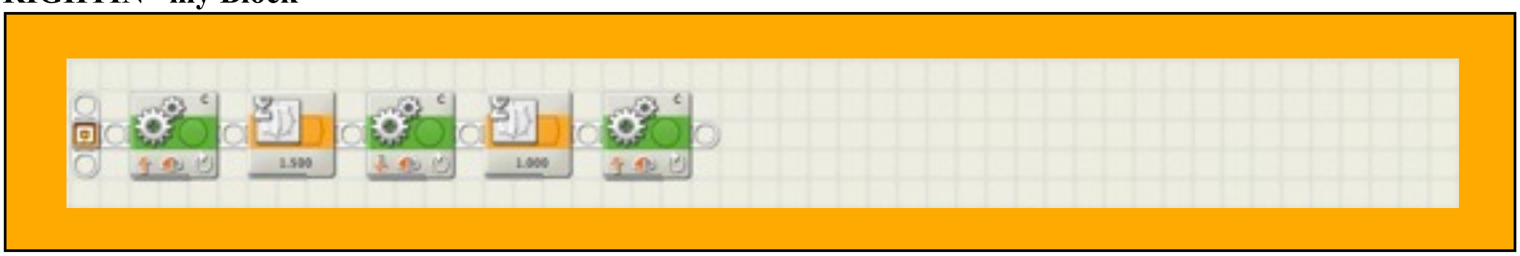


This is the program for the “Slave” robot. He waits for the “Master” to send a message via BlueTooth at each of the “Wait for BlueTooth” blocks. This is what keeps the two robots in sync

Line Follower "my Block"



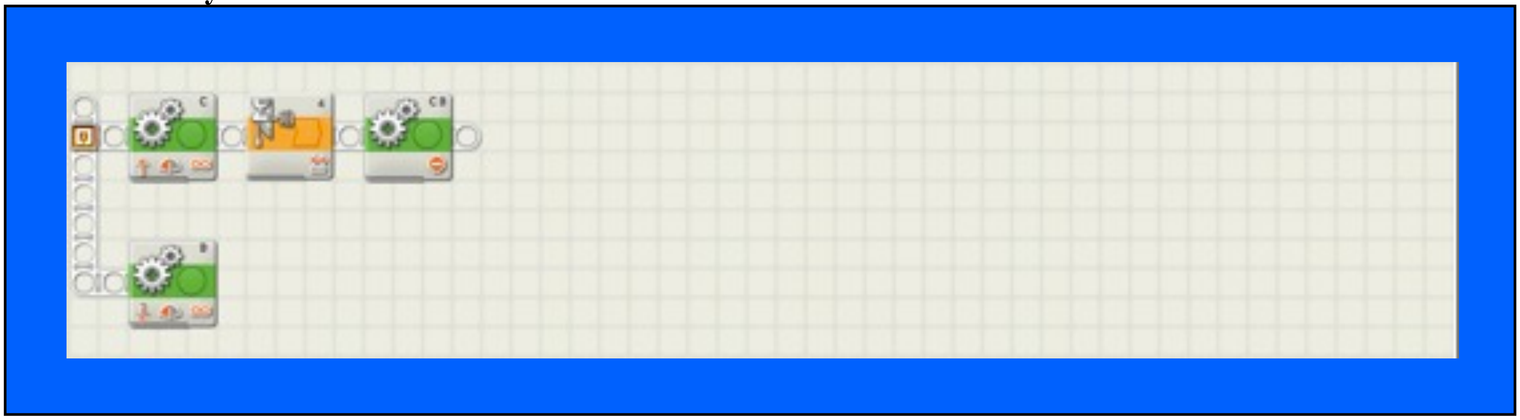
RIGHTIN "my Block"



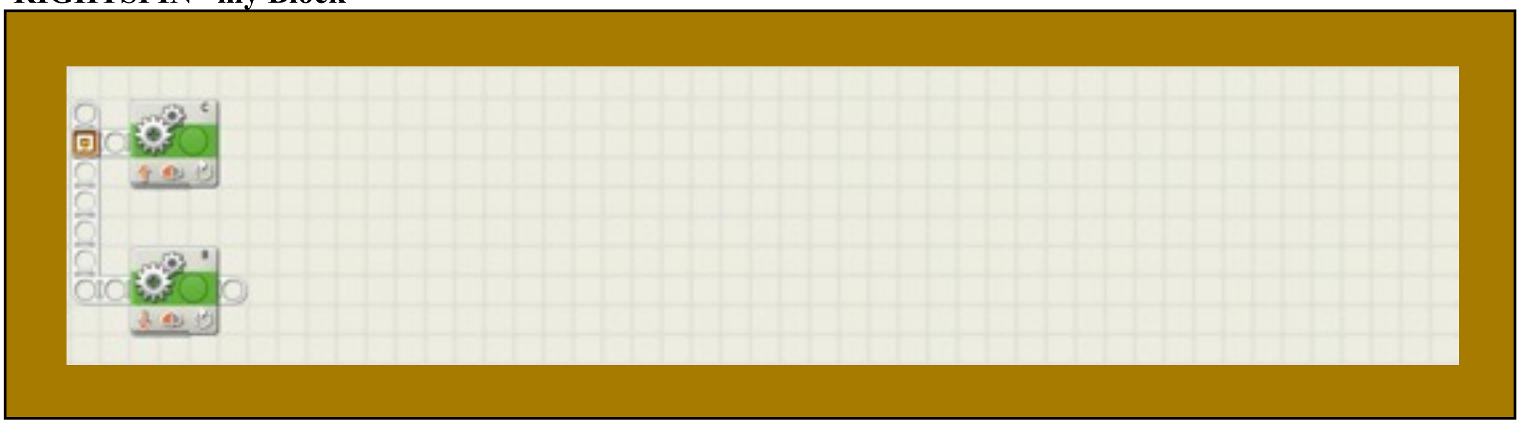
RIGHTSHAKE "my Block"

EXTRASPIN "my Block"

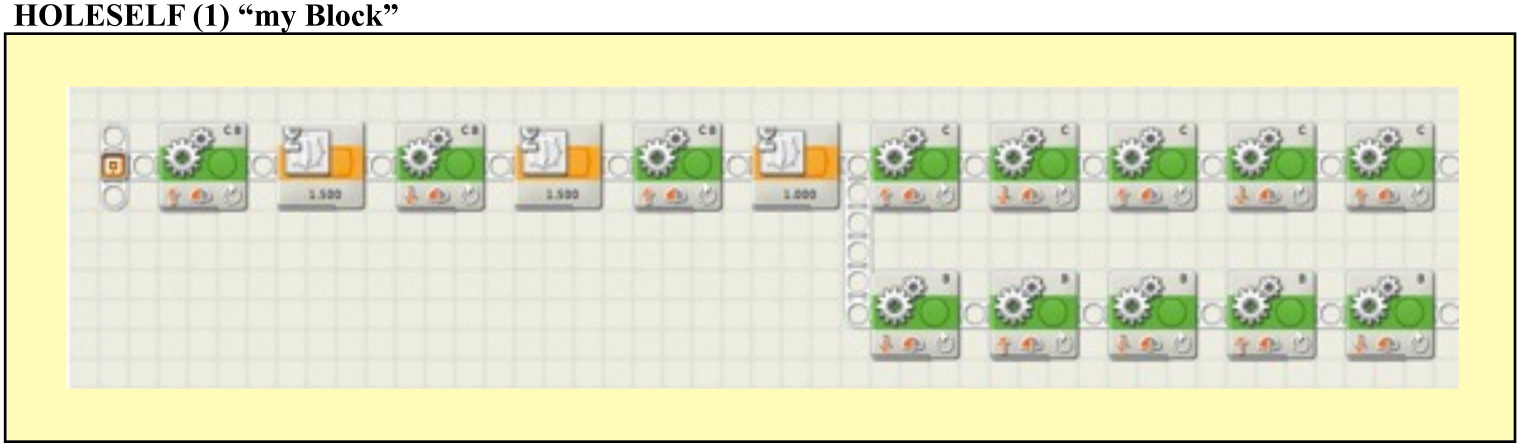
ENDSPIN "my Block"



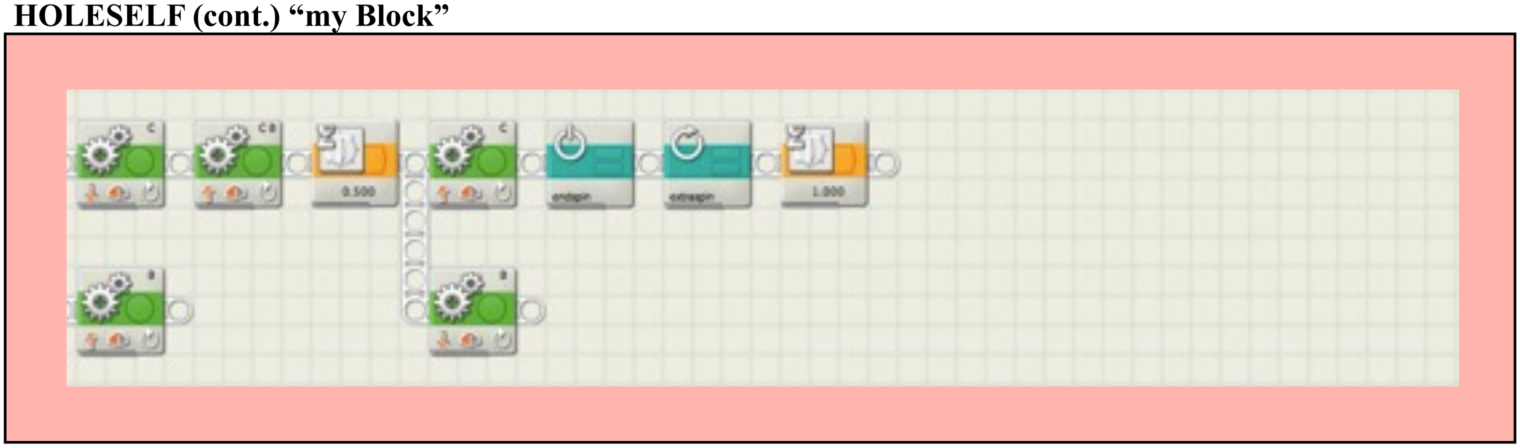
RIGHTSPIN "my Block"



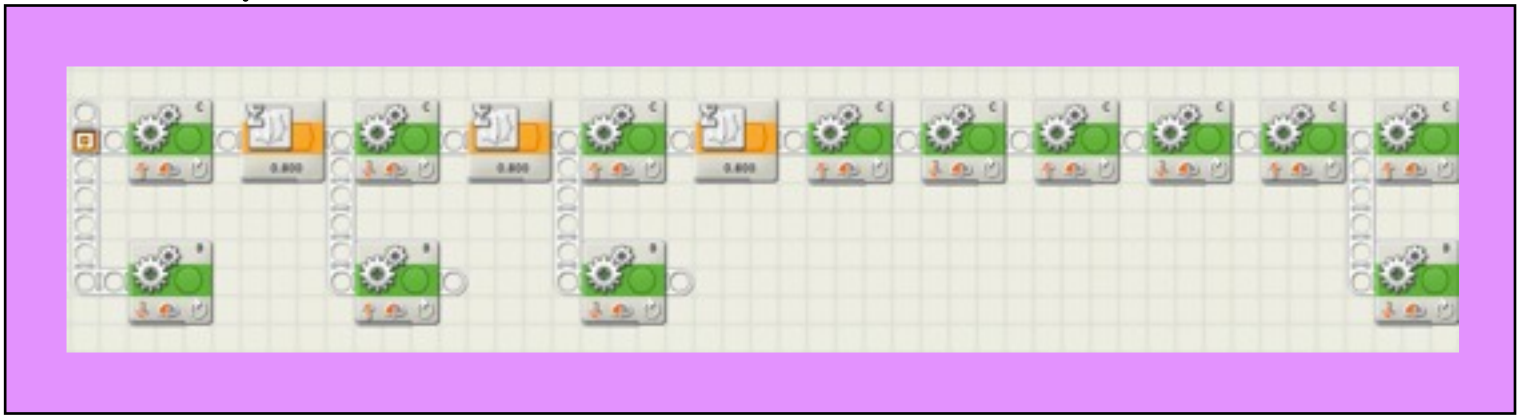
HOLESELF (1) "my Block"



HOLESELF (cont.) "my Block"

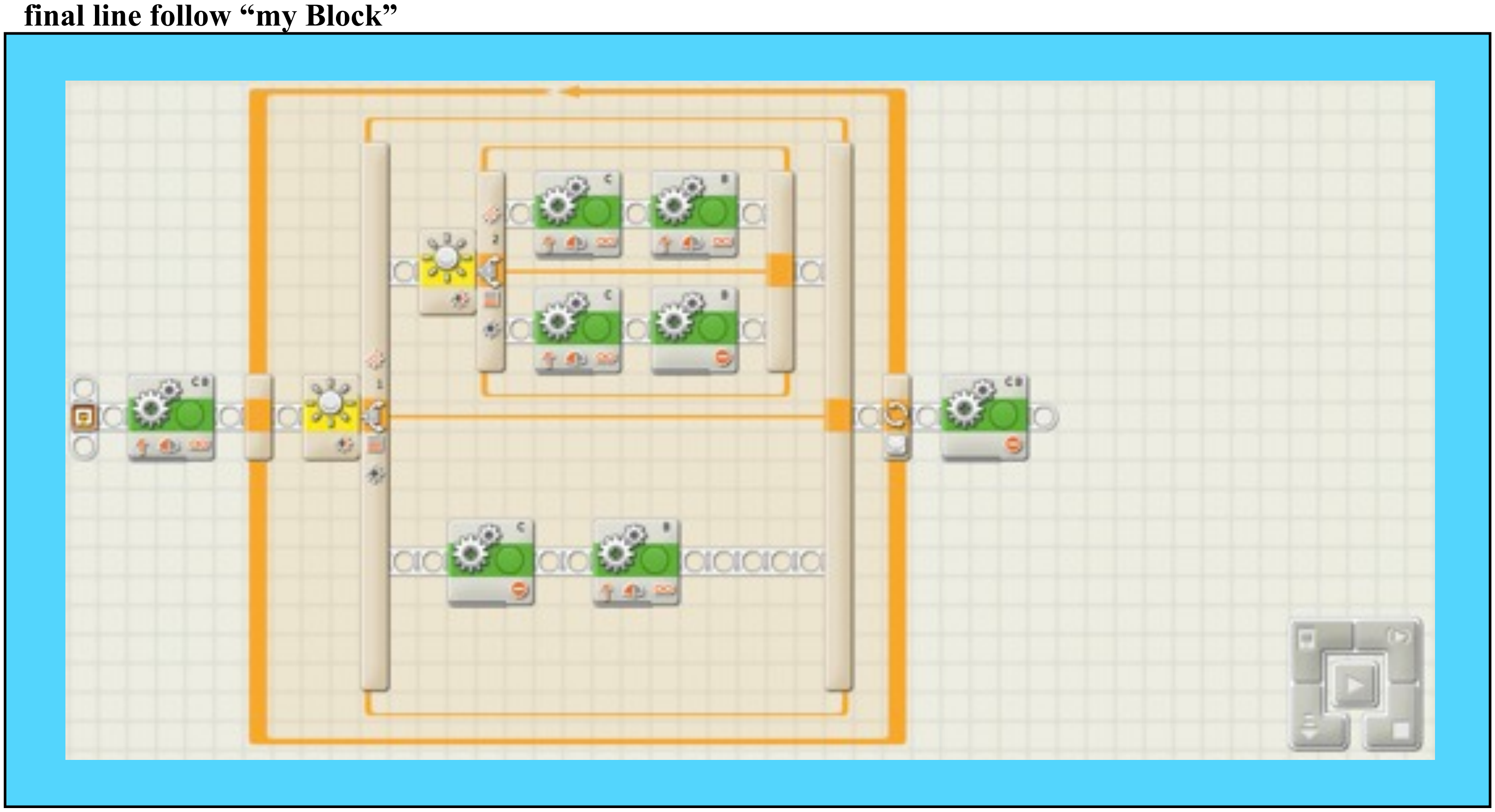


BACKSIDE "my Block"



endblock "my Block"

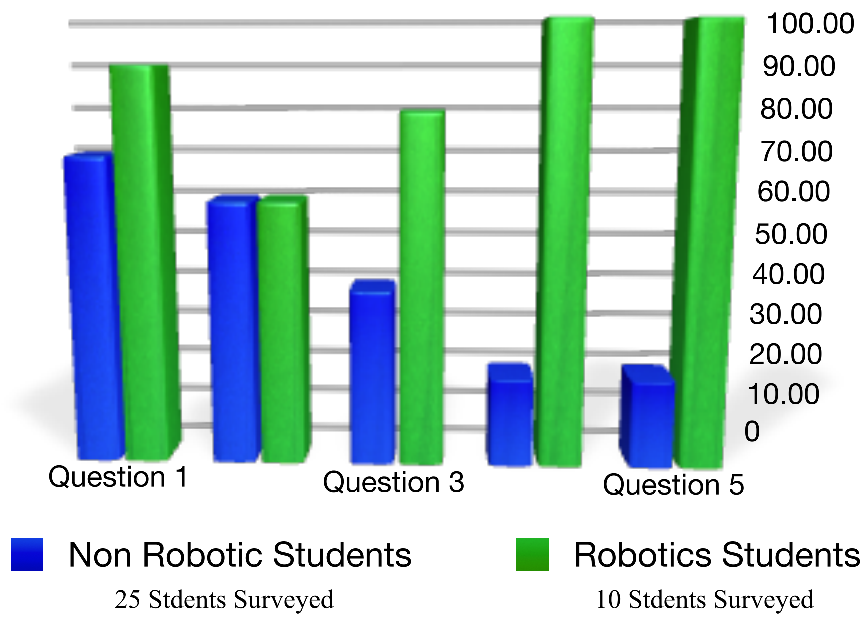
final line follow "my Block"



Survey Results

The main purpose of the survey was to find out whether students who participate in a robots program had different attitudes towards science and technology than those who did not participate in such a program. As the graphs shows students who did participate felt that they did have a better understanding of both math and science and that they felt that they were more likely to pursue a career in either the field of science or technology. There were a total of 10 student that completed the survey that participated on the robotics team, and 25 students that participated in the survey that were not a part of the robotics program. The second part of the survey, questions 6-13, were only given to the students on the robotics students. The results are as follows;

Non-robotics Students vs. Robotics Students



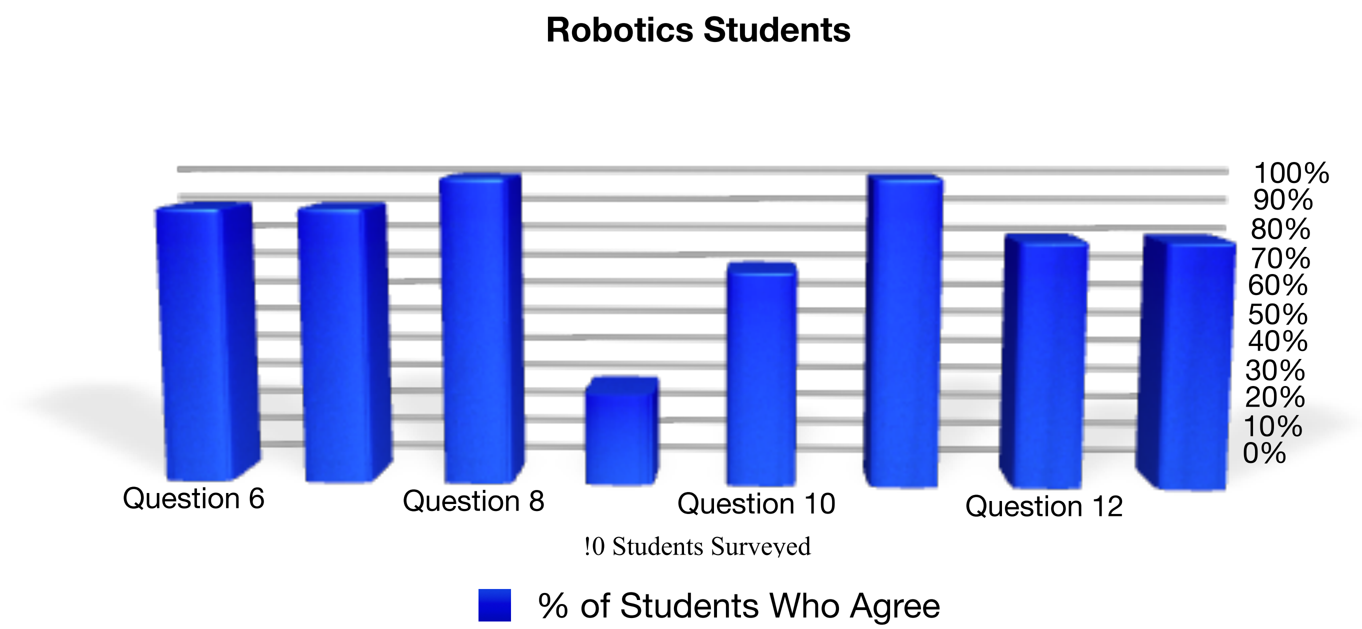
Question 1 I feel that I have a better understanding of Science after this school year.

Question 2 I feel that I have a better understanding of Math after this school year.

Question 3 I feel that I am more likely to pursue a career in the field of either Science or technology after this school year.

Question 4 I feel that after this school year that I will be better prepared to work on group projects in the future.

Question 5 I feel that I am a better problem solver after this school year.



Question 6 I would prefer to be on a team that was made up of both boys and girls.

Question 7 I feel that each member of the team should have a designated specific role on the team.

Question 8 I feel that the team should just meet, and the members just contribute in whatever way they feel most comfortable.

Question 9 I feel that four hours per week is enough time to prepare for a competition.

Question 10 I feel that more than four hours per week is needed to prepare for a competition.

Question 11 I feel that I have learned a great deal about team work and the benefits gained by working on a team.

Question 12 I feel that by participating in the robotics program that I will be better prepared to work on group projects in the future.

Question 13 I feel that I am a better problem solver now that I have participated in the robotics program.

Conclusion

As you can see, when it comes to middle school robotics programs there are many different competitions to choose from. Hopefully the information provided in this paper will help make the decision process a little easier for both current coaches, as well as potential coaches, and some of the suggestions will help improve your team in general.

As for improvements to the competitions themselves, we can only hope that other organizers will follow the lead of Dr. Chung and the organizers of Robofest, in their incorporation of mathematics into the challenges, or at least finding ways to somehow implement mathematics into the scoring rubrics that involve interviews with the kids.

So, you as a coach, or potential coach, need to decide what exactly it is that you are looking to gain from your robotics experience. If you just want to provide a good time for your students, then any competition should do, but if you're looking for a good time as well as a positive educational experience for your students then you need to be a little more selective and take the time to carefully find the competition that will be the best fit for both you and your team.

References

BEST Robotics Inc., Retrieved May 20, 2010, from http://best.eng.auburn.edu/

Botball, Retrieved May 20, 2010, from http://www.botball.org/

FIRST Lego League, Retrieved May 19, 2010, from http://www.firstlegoleague.org/

Robofest, Retrieved May 17, 2010, from http://www.robofest.net/home.htm

Appendix

Table 1

	FLL	Robofest	BEST	Botball
Cost **Initial** **Following Years**	$1000 $500	$600 $150	FREE FREE	$2500 $2500
Maximum Number Of Student Per Team	10	2-3 Per Robot 7 for Robo-Fasion & Dance	None	None
Allowable Kits	Lego Mindstorms	Any	They Provide	They Provide
Allowable Software	NXT-G RoboLab	Any	easyC ROBOTC	KISS-C
Season	Fall	Spring	Fall	Fall-Spring

About the Author
Mike Dobbyn

Mike is a 1997 Graduate of Eastern Michigan University, where he earned a Bachelor of Science in Elementary Education with a major in science and a minor in social studies. He earned a Sheltered Content Endorsement from Wayne State University in 2002.

Mike has been teaching in the Hamtramck Public School System, at Kosciuszko Middle School since 1997, where he has taught science, math & social studies. He has been coaching Kosciuszko's FIRST Lego League robotics team since 1999. Due to the popularity of his after school robotics program the district asked him to turn his program into an elective class which he has been teaching full-time for the past four years. This past year was his first year as a Robofest coach.