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Mentorship in Middle-School Engineering Education
An Interactive Qualifying Project Report
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by

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Approved:
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Abstract

A study of mentoring practices and the results thereof using FIRST Lego League as an example of middle-school engineering education. Data was collected using normal survey distribution methods. Topics of primary concern include team set-up, division of labor, and effective teaching methods. The result is the creation of a handbook for distribution to new teams in the FIRST Lego League program.

Contents

Chapter 1

Introduction

1.1 Goal

There is one primary goal for this project; the creation of an effective manual containing guidelines for new mentors. Currently the FIRST manual for coaches does not provide instruction to new coaches/mentors in effective mentoring methods. Many mentors have commented on the difficulty of the first year or two in the program, and we hope to adress this issue by creating a better set of guidelines for new teams.

By addressing this need, many new teams will be more effective and get more enjoyment out of their starting years. The necessary information falls into three main categories, effective team dynamics, program structure, and curriculum. This handbook will be useful to all teams who would like new ideas, especially in curriculum where even veteran teams tend to have no defined process.

There are many advantages to a handbook written outside of the FIRST administration, primarily the ability to say what is necessary without violating the separation of the FIRST staff and the FLL(FIRST Lego League) teams. Ideally FIRST will recognize this work and distribute it to teams, providing them with tools and experience they would have to acquire without help otherwise.

1.2 Plan

In order to make an effective handbook on mentoring strategies the first step is to collect data on the mentoring strategies used currently. This information could then be analyzed in oder to determine the effects certain variables have on the overall efficiency of the methods involved.

In order to collect enough information to get a general feel for teams in the area, a survey must be designed and administered. This survey should cover topics such as individual skills of each student on the team, the attempted methods of teaching, the preferred methods of learning, meeting times, locations, and team set-up. This survey must be given out to enough teams to ensure that, with an expected fifty-percent return rate, enough information for meaningful analysis will be acquired. This can be most easily accomplished at the state competitions in which most teams participate.

After the required data is gathered, it must be analyzed. Statistical tools such as the SPSS v11.5 for Windows make this process much more manageable than hand calculations or the use of spreadsheet software such as Microsoft Excel. This analysis should be conducted on a team by team basis in order to separate the mentoring variables for easy comparison.

Following the statistical analysis, conclusions will be drawn and a handbook will be designed and written. This handbook will cover the topics of effective team dynamics, program structure, and curriculum in accordance with the project goal. The handbook will be written in a friendly, non-formal format to promote easy and enjoyable reading by prospective mentors.

Additional research topics will become apparent throughout this process, and these should be documented to provide a starting point for future educational research in the FLL program.

1.3 Motivation

The reason to write this manual comes from two years of mentoring experience on a starting team. After the rough first year, a curriculum was developed and implemented, while at the same time the overall structure of the teams was drastically redone. These changes increased the ability of the mentors to help the students and made the program more fun and less stressful for all involved. After seeing the drastic differences in efficiency and hearing the complaints of many teams for more detailed guidelines, it was found that there was a demand for a guidebook for new teams. This guidebook should eliminate many of the issues with new teams and will hopefully make the FLL community a happier one.

1.4 Intended Audience

The findings discussed within have a limited range of direct impact, but also provide a basis for future work in this area. Research in this field is becoming more important as time progresses, and this lays the groundwork for future investigations.

The creation of the mentoring handbook is most important to rookie teams joining the FLL program, but could be used by anyone involved in middle school engineering education. While the specific team-design topics will be of less use in a general setting the examples of introductions to the concepts of programming and mechanical design have intentionally been left broad enough to be applicable in most situations.

The FLL structure is ideally suited for engineering education research. Education research has become more and more important over the last decade as it had become clear that American school systems have fallen behind when compared to the educational systems of European and Asian societies. Many feel that a general understanding in all fields is no longer feasible and are pushing for vocational education as the standard. More research is necessary before any decisions should be made, and the FLL is one of the places where engineering education research can easily be conducted.

1.5 Introduction to Chapters

This document is formatted to fit closely with the Worcester Polytechnic Institute guidelines for IQP papers. The following is a brief explanation of each chapter and the information to be found therein.

Overview of Chapter 1: Introduction

Chapter 1 contains information necessary to introduce the "mentoring effectiveness IQP". This primarily concerns the how and why of the initial project design, as well as some information about who will be impacted by the findings.

Overview of Chapter 2: Background

Chapter 2 is a compilation of prior research that was reviewed along with past experiences of the project group members. This information is very broad and covers topics ranging from "what is FLL?" to middle school psychology.

This background is important for two reasons. First, it will serve as introduction for those who are unfamiar with the topics discussed throughout this paper. These topics are very broad and include multiple educational studies as well as textbook information from education classes. The second reason is to back up and validate findings introduced in later chapters with prior research. This is especially important when talking about the curriculum design discussed in chapters 5 and 6.

Overview of Chapter 3: Procedure

Chapter 3 explains the process behind the research. This includes a step-by-step process description for each phase of the project. The process begins with an analysis of the current FLL situation, describes in detail the creation and implementation of the surveys, and begins a discussion on dealing with the collected data. For more in depth analysis of the data see Chapter 5: Analysis.

Overview of Chapter 4: Results

Chapter 4 provides the first look at the data collected during the Robonautica and Quincy tournaments. Besides introducing the survey data itself this chapter will discuss unusable data and the reaosning behind this decision.

Overview of Chapter 5: Analysis

Chapter 5 provides the details of the analysis of the gathered data. The information gathered which pertains to students, mentors, and teams are individually discussed. This is followed by a look at interdependent relations between students and mentors, as well as the impact of program structure on the overall effectiveness of each team.

Overview of Chapter 6: Conclusions

Chapter 6 relates the findings of the analysis with the initial program goals. Most of the conclusions explained here are found in the mentoring handbook in the appendices. The handbook contains a friendlier text giving the conclusions without the explanations of how they were found.

This chapter also contains the reflections of the authors on the good and bad points of the process and the recommended next step for others to take. Future projects can be easily extended from this point into many different areas which were not explored.

Overview of Appendices

The appendices hold all of the extra documentation and tables not included in the above sections. This includes a copy of the survey forms as distributed at the competitions, as well as a copy of the final mentoring handbook. Copies of data tables will also be included in this section.

Chapter 2

Background

This chapter introduces all off the background material necessary for easy comprehension of the rest of this paper. Information is provided in four sections: detailing the FLL program, the research done on education, prior experiences with FLL. And, lastly, the specifics of one FLL team and its first stages of development. Many of the later conclusions are based on past experiences as well as the survey data, so familiarity with the background material is important.

2.1 FIRST Lego League Overview

To understand FIRST Lego League it is important to understand FIRST itself. FIRST (For Inspiration and Recognition in Science and Technology) is a 13 year old program. The goal of the FIRST program is to interest high school students in science careers through a robotics tournament. The rules are fairly simple. Each year the game is changed to provide a new challenge. Teams consisting of primarily high school students, with either adult or college members, build robots to compete in the year's game. The build season is six weeks long, from the unveiling of the new game to the ship date required for participation. Regional competitions are held in all areas of the USA, as well as portions of Canada, and these regional events are followed by the national competition. At each competition awards are distributed, the most prestigious of which is the national Chairman's Award given to the team who best shows the attitude of FIRST, not the winner of the competition.

FIRST Lego League is simply an extension of the FIRST principles into an audience not yet ready for 130 pound manually-machined robots. Instead, FIRST partnered itself with the Lego corporation to allow the students to build lego robots. These robots follow the same general list of parts as the Lego Mindstorms robotics package that is available for purchase most places Legos are sold. By providing a quick building interface with an easy to learn programming platform, FIRST is now able to inspire students between the ages of 10 and 14, as well as the high school students with which it began.

While based on the FIRST model, FLL(FIRST Lego League) differs in a few important areas. As discussed previously, the robot materials are very different, as are the core students on the team. In addition to the different students one sees a very different mentor selection among the FLL teams as well. Instead of being a professional in the field of engineering, which is almost required for FIRST, most mentors in FLL are team-members' parents. Another difference in the mentoring staff is the inclusion of high school students. who oftentimes are involved in the high school FIRST program. This new team dynamic makes FLL a very different experience from FIRST.

The other difference between FIRST and FLL is the game-play. In FIRST the robots are primarily human-controlled by radio, yet in FLL all robots perform their tasks autonomously based on the preloaded programming. This is one aspect of the real-life games designed for FLL. In real life situations, you cannot always remote control your device to do what you need; often it will need to perform tasks autonomously. A good example of this is the Mars Rover which collects samples and explores the Martian surface without direct human control.

Real-life games simulate actual problems as they exist in the real world. FLL games are based on real robotic challenges such as arctic and Martian exploration, as well as city dwelling challenges of rubble clean-up and building construction. FLL teams are also required to perform research on the year's challenge, and thier findings must be presented at competition. These real-world features provide students with an early look at what technology does for people, while remaining a fun challenge at the same time.

FLL is a growing program, with more teams joining each year. Already there are multiple tournaments in certain states, and more competitions are expected to be formed over the next few years. This is similar to the expansion of FIRST, which will have over 1000 registered teams across the country by next year. Obviously, mixing fun with science is a winning combination, and the FIRST programs seem to be accomplishing their goal of interesting youth in science and technology.

2.2 Literature Review

Curriculum Improvement decision making and process

By Ronald C. Doll

Humans are constantly changing the method that should be used to teach. In the book Curriculum Improvements: Decisions Making and Progress, Ronald Dell offers an in-depth explanation of how to form and make changes to a curriculum. Curriculum has different meanings to different people but, in general, it represents material that is taught and how it is taught. A curriculum is frequently changed because of the changes in the world in regard to social and cultural influences. There are many points to consider when designing a curriculum.

Krathwohl, Bloom, and Masia have devised a method to organize all the classifications and subject matter available. This method is called taxonomies. Taxonomies are broken up into three groups: cognitive (based on intellect), attentive (based on feelings), and psychometer (relating mental activity with physical activity). By gaining a firm grasp on taxonomies, teachers are able to expand their curriculum with a larger/broader range of objectives.

In addition to taxonomies, there are varying levels of knowledge that, when presented to students, can increase understanding. The most basic level is specific facts. The second level is basic ideas and principles. Basic ideas and principles are an essential addition to the facts because they add reason. The third level is concepts. Concepts are also an important part of education, but the difficulty lies in the fact that students cannot be told this information; they must develop it on their own. The final level is thought systems. Thought systems allow students to apply knowledge and relate it to other ideas, then expand on the knowledge. The levels of knowledge help to make teaching objectives smaller and to break down complex subjects.

Evaluation of a curriculum is normally based on the evaluation of student progress by teachers inside the classroom, by outside sources such as the school board, and by evaluation by national or state departments. Inside the classroom evaluation instruments can include tests, checklists, journals, interviews, portfolios to name a few. These instruments can help a teacher to formally and informally evaluate frequently. Teacher self-evaluation is also an effective way to make positive changes to education.

One method of determining effectiveness of school systems is through surveys. These surveys are most successful when performed by an outside group looking in. Visits and interviews contribute to the overall picture of the curriculum that the surveyors hope to see. Self-surveys are also useful, especially in combination with the above. These combinations help overcome the biases that may be reflected in individual surveys.

When the goals of a program are established, thought should immediately be focused on how to evaluate these goals. By concentrating on the methods to evaluate the goals, it is possible to see how feasible the creation and monitoring of these goals are. When thinking about evaluation of goals, it is also important to establish standards for evaluating educational achievement. Often, if enough people use the same system it can become a standard for that particular situation. The standards should be frequently checked and rechecked against the goals. The ultimate purpose of evaluating is to produce findings that have meaning.

Evaluating an entire program is very different from evaluating one teacher or one class.

Evaluations often require surveys simply because of the magnitude of the task. These surveys help participants to improve the overall curriculum. Due to a larger group size, their standards may also be more general in nature. Before deveolping the survey, it is important to have an understanding of what criteria is to be analyzed with this evaluation. Any evaluation should consider the effectiveness of the delivery system, the educational environment, the learners, and the learning. To ensure the quality of evaluation, make sure goals are outlined. Also the students participating in the study should represent all of the participants in the program. Students should be measured based on the desired characteristics decided upon prior to survey creation.

While the study is underway, a formative evaluation should be conducted and, after completion, a summative evaluation should be administered. These evaluations should be used to form conclusions, which should then be used to make changes to the program.

Formal evaluation usually occurs in three stages. The first stage is process evaluation or the stage for assessment. Formative evaluation is the second stage, which is performed during the implementation. The final stage is summative evaluation, which occurs after everything is completed.

In his book, Doll is very descriptive when explaining different theories and aspects of curricula. There are many, many things to consider when starting up a team, yet one must remember that the most important part of FLL is teaching the students. Doll offers many ways of evaluating a program depending on the characteristics of the group. Overall, this book is an important tool for someone designing a curriculum.

Teaching in the Middle and Secondary Schools

By: Joseph F. Callahan, Leonard H. Clark, and Richard D. Kellough

Middle school students are at an age when they are changing into adults. The individuals change frequently, and this makes teaching them a challenge. Most middle school students are very motivated and active, but they are very susceptible to peer pressure. In an effort to define their own personality, adolescents often exhibit a variety of characteristics.

One of these characteristics is egocentrism. This means that members of this age group seem to find importance in only what applies to them. This is very common in younger children, but when a person reaches adolescence and is beginning to act like an adult it becomes more noticeable. One result of adolescents being very preoccupied with themselves is that they are not good at listening. It may be frustrating for a teacher who is faced with students who have trouble listening, but it is important to remember that it is necessary for adolescents to learn how to develop listening skills. By being patient you can teach them the importance of that skill.

The next characteristic is interpretation. In order to adjust to the frequent changes in their lives, adolescents are continually trying to interpret their surroundings. By making these interpretations, they are able to conduct a meaningful life. Interpretations are not just made about their surroundings; they are also used to analyze experiences and merge the past with the present. As middle school students expand their minds they are able to think more abstractly, which causes their interpretations to change frequently.

Students in this age range also often exhibit characteristic persistence. To fit in with their changing beliefs, adolescents are willing to spend a great deal of time working at things that they enjoy.

Curiosity is another factor in children of this age range. Commonly, adolescents are more interested in things that move, make things happen, and, most significantly, things that appear to be magical. You can be more effective during instruction by taking advantage of their natural curiosity.

Another characteristic is their desire to explore. Adolescents love to take things apart and put them back together. They love to discover new things and ask many questions about the world. In a learning environment, it is beneficial to encourage children to ask more questions because it helps them make sense of the material.

Adolescents are normally very energetic. This means that oftentimes they are not able to stay in one spot for long periods of time. This makes it hard for students to concentrate. When teaching, it is important to understand this trait.

During their stage of adolescence, children are very concerned with acceptance by peers. Group work helps build self-esteem and gives students a clear direction. It is very important to incorporate methods to build social skills into your teaching strategies.

The last characteristic is need for self-growth. Every human in existence has basic needs. Some of these traits include security or the need to feel safe, physiological or social self-actualization, and a sense of self-esteem. When students do not receive the these basic needs, they become unable to perform in a learning environment. Some students will begin to disrupt other members of the environment, while others will become very antisocial. When basic needs are not met it can be the responsibility of the teacher to recognize these needs are lacking, but it is not the teacher's responsibility to try to meet all of the child's needs personally.

Many teachers find middle school a very difficult environment in which to teach . By researching this age group, scientists and teachers are able to better understand how to deal with the frustrating aspects of working with middle school students. Below are some of the significant learning theories that have been developed.

Jean Piaget made many contributions to understanding mental developement. He claims that from birth to post adolescence there are four stages of mental development. These stages cannot be skipped, and they occur at different points of time for everyone. It is important to be aware of varying degrees of development when teaching a group of students because, if a student is placed in a situation they consider too difficult, then they may start mentally downshifting or going back to earlier learned behaviors. There are many situations researchers believe have the potential to start downshifting. These include, but are not limited to, when past knowledge does not agree with what is being taught, the return is not immediate or controlled, time lines are limited, and/or the work being learned is too foreign and help is not available.

The stages that Piaget lays out are the sensorimotor stage, the preoperational stage, the concrete operations stage, and the formal operations stage. The sensorimotor stage occurs between the ages of birth and two. Learning comes from direct interaction, which helps the child to build mental capability in regard to actions.

The preoperational stage occurs between the ages of two and seven. During this stage, children often are able to move beyond just acting, and will think through actions before doing them. In this stage, there are no logical operations behind the thinking; the thoughts derive simply from egocentrism. Decisions are made based on subjective views. This can be the source of many 'why' questions. Another aspect of this stage is that children can concentrate on one object at a time, but they are often not able to look at many different characteristics of one object. They are not able to put together complex series, and they cannot understand the concept of conservation. During this stage, children do not understand how to reverse a process. This means that children in the preoperational stage normally learn best by hands on activity where they can manipulate and control objects.

The third stage, the concrete operations stage, occurs between the ages of seven through eleven. During this stage, children begin to execute logical operations, giving them the ability to observe and weigh possibilities. These advancements help children learn to solve physical problems. This is also the point when children can arrange objects in a long series and understand reversibility. At the end of this stage, children can form hypotheses and generalize. During the concrete operations stage active learning is most effective.

The final stage is the formal operations stage, which usually begins at the age of 12 or later. At this point, people's thinking changes and becomes more abstract. They become capable of higher level thinking and relating many ideas. They are able to develop and test theories and make conclusions.

Based on these four stages and other investigations, researchers at the University of California at Berkeley developed a three phase learning cycle. These phases are used to guide students from active hands-on learning to more abstract learning. The first phase is an exploratory, hands-on phase. This is the stage where students begin to explore and come up with tentative conclusions. The next phase is the concept development stage where students are taught to develop theories under the supervision of a teacher so that they can ask questions. The final stage is the concept application phase where students try out their new ideas.

Robert Gange is a behaviorist who developed theories on different learning levels. Gange defines learning as having the ability to do something that you could not do before. The way of measuring learning is through observing a change in behavior. As you move through the learning level hierarchy, each stage depends on what was learned before. The simplest of the eight learning stages is signal learning. This level is where a person learns to respond to a simple signal. The next stage is stimulus-response learning, where a person develops a vocal or physical reaction to a certain event. This is different from the first stage because the response is more than a facial expression. The third stage is chaining, where learning occurs by making associations between two stimulus-responses. This does not include vocal responses, only physical. Next is verbal association, which builds on chaining in that the links become verbal. The level after verbal association is multiple discrimination. During this stage, a person continues linking learned chains. The sixth level is concept learning. In this level, the person learns to use abstract characteristics to respond. In addition, the person begins to learn more thoroughly, and not by trial and error. Principle learning is the level in which one learns to relate many concepts. The final stage is problem solving, where the concepts that are learned can be applied. Children in this stage are able to handle performing new tasks. Throughout this progression, once one of these levels is achieved it is assumed that all the previous levels are known.

Characteristics of Intelligent Behavior

Characteristics of intelligent behavior are important for a teacher to understand in order to teach. Persistence, the tendancy to keep trying, is important for learning. As adolescents get older they begin to exhibit more persistence. Another characteristic is decreasing impulsivity. This is when students are beginning to develop their ability to think before they act. There are many situations in a classroom that can help students learn to control their impulses.

Another characteristic is listening to others with understanding and empathy. This is a notable trait because it allows people to express their ideas and understand what others are saying. Other characteristics are cooperative thinking and social intelligence, flexibility in thinking, metacognition, striving for accuracy and precision, a sense of humor, questioning and problem posing, drawing on knowledge and applying it to new situations, taking risks, using all senses, ingenuity, originality, insightfulness, creativity, wonderment, inquisitiveness, curiosity, and enjoyment of problem solving.

Styles of Learning

Every student has a different background, ability and style of learning. As an educator, it is important when teaching a class to present information in different forms to suit different children. Awareness of different learning styles allow teachers to be aware of how their students learn, thus being a more effective teacher.

Brain laterality is one theory that relates different learning types. When the left-brain is dominant, verbal learning and logical thinking are frequent. Whereas the right side of the brain is where intuitive, emotional, and visual thinking are more dominant. When teaching a group of students by using the sensory input channels, you teach to both sides of the brain.

Learning modalities are another way to gauge how people learn, and to determine their preferences towards learning styles. Some people like to listen, others prefer to see what they are learning, and some prefer to touch. Preference of learning modalities does not necessarily dictate the most effective learning modalities for each person however. During adolescence, most people are not sure what learning style they prefer. That is why many learning styles must be incorporated into the curriculum. Particularly in middle school, it is hard for students to learn primarily through listening. For most students, interactive learning, where students are able to touch and move around during the lesson, is the most successful approach.

Learning styles differ from learning modalities in that learning styles are an *'Independent form of knowing and processing information'*. Learning style is merely an understanding of how a person learns. This is in no way related to the intellectual capabilities of a person. McCarthy illustrates four different learning styles. The first of these learning styles is the imaginative learner. Someone who is an imaginative learner absorbs the most information when listening and then relating what is being said to personal experiences. The second type of learner is an analytic learner, one who favors learning sequentially and benefits from in-depth knowledge that only professionals can offer. Next is the common sense learner, who processes information actively and benefits from hands-on learning. Common sense learners like to see the practicality and immediate advantages of the material. Finally, there is the dynamic learner who likes frequent changes so there is always new information being presented. Dynamic learners prefer hands-on learning and do not respond well to monotonous material.

Howard Gardner offers an alternative analysis of styles of learning. He has developed a list of 'learning capacities'. They are: kinesthetic, or the ability to use your body; interpersonal, or the ability to understand others; intrapersonal, or the ability to understand emotions; mathematical; musical; naturalist, or the ability to recognize different plants and animals; verbal-linguistic, or the understanding of words; and, finally, visual-spatial, or the ability to portray the world through art. These characteristics are more diverse that McCarthy's four learning styles because many people exhibit more then one learning capacity.

Lev Vygotsky is another psychologist who devolved theories on education. He practiced many of the same ideas as Piaget but with some differences. The main difference is that he stressed social interactions. He thought that learning was most effective when in groups.

A supportive learning environment

Learning styles are an essential part of being a successful and valuable teacher. This means that one way to help students learn is by making sure they are in a supportive learning environment. Students must understand that they are welcome, and they must be comfortable in their surroundings. They also must feel as though they are challenged, while at the same time knowing it is within their capabilities. Getting to know the students and recognizing them as people increases their comfort and helps them to learn. As time progresses with the students, you should be able to know all of the children's styles of working, preferred learning modalities, needs for structure, and interests.

Group Learning

Cooperative learning groups can be a great way to help students learn. A cooperative learning group normally consists of a few students of mixed ability and gender. During the duration of the project at hand, the group can learn about one another and learn about their own strengths that they brought to the group. There are often roles assigned to each member in the group. Roles help to make sure everyone in the group participates. As a result of cooperative learning groups, students often exhibit better academic achievement, better communication skills, and a stronger ability to stay on task.

Making Students Think for Themselves

Thinking skills can and should be taught in every classroom and in any class. Early on, thinking skills are taught by explaining a skill set and rewarding students for using those skills. By adolescence, students should be able to think logically, and thus identify and solve problems. Practicing thinking skills is a very important part of becoming a good learner. As skills progress, students will change from having to solve a problem that someone else presented to a point where they identify their own problems. Projects and papers are a good way to continue practicing these open-ended thinking skills.

When helping a student with projects it is important to provide coaching guidance as necessary, but leave room for the students to have some control over the outcome. This entails letting students design their own project plan and offering feedback primarily when asked. Constructive encouragement is key to a student's success, as is letting them make their own mistakes. Written guidelines and timelines help many students to stay on task, but it can be beneficial to have the students work on making these timelines themselves.

The Art of Teaching

By: Gilbert Highet

In the book The Art of Teaching, Highet stressed that teaching is not a science. He claims that there is no set formula for people to follow in order to be good teachers. Instead teaching is an art where everyone has a unique style. His theme throughout the book is, " You must throw your heart into [teaching], you must realize that it cannot all be done by formulas, or you will spoil your work, and your pupils and yourself."

Highet outlines three ways of getting information across to students. These are lecturing, the tutorial system, and use of preliminary classroom work. Lecturing is where the teacher stands in front of the class and talks while the students listen. Delivery is a very important part of lecturing. Avoiding filler words and misplaced pauses is key to keeping your audience interested in what you are saying.

The tutorial system is a method of teaching where the teacher asks questions to try and make the students draw their own conclusions. This method is very difficult because it requires alert students and an alert teacher. The tutorial system, when done correctly, gives the student a very in-depth understanding of the concepts, but it requires a great deal of time and money. The teacher gets to know the student very well, and accommodates his or her learning preferences. In this method, the student prepares work and then brings it to the tutor, who goes over it. The success of this method hinges on the fact that the student faces the material three times. First, when preparing the assignment then when going over the material with the teacher, and finally when correcting the mistakes or arguing the errors.

The final type of presentation with preliminary classroom work is the most common. This method primarily relies on memorization. The educator has two primary goals. The first is to answer questions and make sure everyone understands what they worked on, and the second is to make sure that everyone did the work. One reason why this method is so common is that assessment of a student's knowledge is very easy.

The art of teaching could also be helpful to mentors. The problem is, in order to get to the useful advice you have to sift through the negative critical comments that dominate the book. It offers many examples of what not to do, but also has very useful comments on what will make a stronger teacher.

Powerful Play:

Using Toys as Tools in Engineering Education

by: Phillips, Palazolo, Magun-Jackson, Camp, Schmucker

In this study researchers used toys with different teaching techniques to help lay a strong foundation for engineering students. By using many different toys they were able to conclude that there is a strong correlation between toys and the depth of material that is learned.

In addition, toys helped students to give a clearer and more detailed explanation of the material. Observers claimed that students seemed to 'internalize' the information better.

Lego Robotics in Engineering

by: Lau, McNamara, Rogers, Portsmore

In this study students are taught robotics and engineering principles using Lego, RCX, and ROBOLAB. Through this study researchers concluded that using these tools provided a far more effective teaching strategy than traditional classroom-based methods. These tools are relatively inexpensive and can be quickly set up for lab sections. The parts are easy to replace, so it makes it very cost efficient, especially for students who have no experience with programming or building. The most important aspect of using Legos to teach engineering is that they can be used at every level of education. Kindergarteners can build at one skill level, while seniors in college can also benefit from lessons with Legos.

Schools for Middle Years

by: Stoumbis, Howard

Concerns of Contemporary Adolescents by: Richard Schmuck

In general, middle school students have very healthy personalities. Their primary concerns are not about understanding the demands of the present and the future, but more about trying to understand and meet the goals of their parents, teachers, and peers. To determine the concerns of adolescents, Schmuck questioned three groups of teenagers. The primary concerns reported by the students were about teachers not knowing their students, teachers not having interest in the material, and teachers showing preference to other students. Another major concern was with peer relationships. These concerns included self-values not agreeing with those of friends, not fitting in with friends, and maintaining popularity.

Another finding of this study was that teenagers are not alienated from the adults in their lives. In addition, they are not trying to rebel against society or the values that are being instilled in them. What makes them difficult to understand is that they are struggling with how to pull together the many ideas and expectations of their elders while creating their own identity. During this period they are more aware of the values of people outside their family, that puts teachers, mentors, and peers in an essential role of helping adolescents to understand themselves.

Social Change: Impact on the Adolescent
by: James Coleman

Teenagers and adults have been notorious for having difficulties in communicating with each other. Coleman claims that one of the main causes of these miscommunications is frequent changes in the lives of adolescents. Adolescents are very open to new ideas and experiences, which makes them unwilling to concentrate on one thing for a long period of time. At the same time, teenagers are less willing to be taught by or to respect a teacher merely because he or she is in the teacher position. This means that teahcers must earn the respect of the students they teach. This agrees with the other studies in that many teachers are less desirable if they favor other students too much, or if they do not understand or show interest in a student's work. In order to get the most out of a student, a teacher should be fair and attempt to maintain interest throughout the class. In middle-school situations, this can best be accomplished through interactive learning as described previously.

Using all of the information gathered can be a daunting task, but much of it is very useful when trying to educate students in this age range. As these topics become applicable to indivual findings throughout the rest of this project, these ideas will be mentioned, hopefully providing useful examples of these concepts as well as backing up the findings of the survey.

2.3 Mountview Case Study

This section is an introduction to, and discussion of, two years on the Mountview Lego League teams. These two years were very different experiences for both the coaches/mentors and the students. By examining differences between the start-up year and the second year, in which a full curriculum was developed and taught, a real-world analysis can be conducted.

2.3.1 Year 1

The first year at the Mountview School was a typical team start up in a school based setting. This allowed the Mountview team to have a defined meetingplace and plenty of space for their groups, something teams occasionally lack. During the first year, the team space was a communal area in the school cafeteria, as well as the computer lab in the library for use by the programmers.

During the first year, 30 students signed up for the FLL program, and these children were split into four official teams. During the group assignment process no consideration was made to age, gender, or ability; it was a purely blind selection process. The mentors on these teams were high school students from the Massachusetts Academy of Mathematics and Science at WPI. These mentors satisfied the FIRST guidelines of experienced technical mentors to assist in "inspiring" the students. Coaches were parents of the team members, all of whom followed the lead of Mr Sherman, the program coordinater.

Throughout the season, the initial teams abided by the FIRST guidelines wherever possible. Mentors did not officially teach the students, but instead helped when problems arose. The teams met for the recommended two sessions per week for two hours each session. Also following the first guidelines, students were selected from each team to perform the required tasks of programming and mechanical construction. Research was not a required aspect of the competition at this time. Using this breakdown the teams were moderately successful. They arrived at competition with completed robots which could perform many of the desired tasks.

2.3.2 Year 2

The second year at Mountview was drastically different from the first year. The teams began to form and meet before the actual build season. This process was much more complicated than the prior year and followed these steps.

Initially, all of the students who showed up for the first meeting were invited to participate in the preliminary teaching process. During the second year, the mentors implemented an official curriculum for the students, with guided lesson plans and tests for progress. This allowed the 150 students who first showed up to be winnowed down to 5 usable teams of 8. Team selection was decided depending primarily upon attendance and test evaluations.

Instead of a communal meeting area, where distraction was rampant, the teams met in individual classrooms in the school immediately surrounding the library area. This helped the mentors to control the students and gave the teams a chance to develop their own ideas, rather than trying to copy surrounding teams.

In this team breakdown system the mentors had become acquainted with students prior to team selection and the students were split up with intent to create balanced, capable teams. Balance was maintained between not only skills, but also between personalities when possible. With the increased interest during the second year, there were enough female students to form an all female team with female students, mentors, and coaches. The outcome of this all female team was no different from any of the other teams, and gender played no role in the success of the students or their robot.

The students' performance increase during the second year of the program was much greater than originally anticipated. The training of the teams doubled the knowledge base of students who participated in the testing process. This increase in experience and know-how led to a direct increase in performance during competitions.

It was also easier on the mentors the second year, due to the instructions they were given for teaching the students. Many of the adult mentors the first year were unfamiliar with any of the necessary engineering skills, but reading the hand-outs prior to lessons in the second year gave them a head start. Thus they were able to provide help to the high-school mentors in areas other than discipline.

During the competition season itself, only certain teams were selected to save on costs to the school. By sending two teams out of the possible five, the Mountview program only needed two official FLL numbers, which saved on registration fees. In order to select these two teams, a mini-competition was held at the Mountview school to assess the progress of each team.

Overall, the second year program was superior to the first year's program because it produced knowledgeable students and more successful outcomes in all areas . This validates the creation of an effective education program prior to the build season. Instead of just tossing the students into the program, the goals of technology education are better met by introduction in a structured way.

Chapter 3

Procedure

3.1 Analysis of Current Situation/System

Before designing any new system it is important to analyze the current situation. In this case a detailed examination of FLL is required before any new measures are taken. As a result of the idea to create a new handbook for beginning teams, it is especially important to look at the current guidelines as presented by FIRST, including the reasoning behind the amount of guidelines they provide.

FIRST Lego League is very heavily influenced by its parent system, FIRST. In FIRST it is most common for new teams to arise due to a partnering with a veteran team who already knows the situation and how to be successful. This outreach to expand the program is the primary goal of the FIRST program, for as the number of teams increases, the interest in the program can only follow.

FLL attempts this same system of partnering, but it is too easy to start an FLL team alone, and the program as a whole is expanding too quickly. Instead of each new team being started by an experienced team, many rookie teams are formed by one student and his or her friends in their home. Instead of receiving guidance from people who already know the ins and outs of being an FLL team, they must learn everything on their own.

In FIRST, it is also very unusual for non-experienced people to attempt to be mentors. However, in FLL, most mentors are parents who may or may not know a lot about Lego robotics. This is another reason why FIRST does not try to provide detailed help to teams, as they assume that the skills are already present in the form of experienced mentors. For more information on the specifics of the FIRST and FLL programs, see Chapter 2 Section 1.

As a result of this system, the FIRST organization has released a very limited amount of information on beginning a new team, and these resources are inadequate. Instead of providing help, the current material states repeatedly that being a coach/mentor is fun and you can figure out how it works on your own. The only formal instruction it provides is a discussion the responsibilites necessary for a team to complete a working robot, and instructions to create a timeline detailing individual tasks and expected completion dates. This is not enough information for a rookie team, as they have never been told what the tasks they need to meet are, or how long the different aspects of robot creation can take. No introduction at all is provided on the different skills necessary, such as programming or mechanical design. It is expected that these will be taught by experienced personnel, as mentioned above. Overall, the FIRST materials lack many of the important guidelines for structuring a team, as well as introductory information necessary to get a team started on the creation of a robot.

Based on the opinions of current teams, all of whom have gone through the rookie process, a guidebook for new teams would be greatly appreciated. Even veteran teams express interest in a guide for teaching the individual skills, an important part of the mentoring process. This guide should cover the basics of creating a team, from breaking up the workload on a team, to teaching the students, and preparing for competition. It is with these points in mind that the survey was designed and research conducted, all aimed toward the creation of a viable guide for new teams.

3.2 Plan Overview

After analyzing the current situation it is possible to form a detailed plan of action. This plan can be seen in greater detail in Chapter 1 Section 2: the following steps are necesary if an action plan is to succeed. This plan outline will briefly list these necessary steps, with reference to the section in which they are discussed.

- Create data collection tool (Form Design (Chapter 3 Section 3))
- Collect data (Collection (Chapter 3 Section 4))
- Perform statistics and analyze data (results and analysis (Chapters 4 and 5))
- Draw conclusions based on data and initial goals (Conclusions (Chapter 6))
- create handbook (handbook can be found in appendix A)

3.3 Survey Form Design

3.3.1 Form Structure

Generating data about groups of people is often a daunting and frustrating task. It needs to be approached correctly and with care from the beginning if the data gathering is to succeed. The most important part of a survey is the form design itself. The layout is the first thing the subjects will see of the project, and the questions on the form are the only method of extracting the information that is desired. Therefore, the visual design, and appeal of the form, is just as important as the content, and both receive equal thought in survey preparation.

The first step to designing the form is determining how the questions are to be laid out, and whom is going to be asked what. Each category of people on a team (mentors, students, or coaches) can be asked different questions to analyze their individual perspective.

This difference in perspective creates a dynamic interaction between mentors and students based on experiences unique to their team. That interaction is what we are investigating. To analyze the different perspectives we first know that there will be a Mentor Form and Student Form, each crafted to extract information from that respective team members. The only potential problem with this is the student's self-report. There should be some method to make sure that the student is reporting him/herself accurately. The solution is simple: create a brief form that the mentor or coach fills out about each student. Born out of that necessity is the Mentor 2 Form.

With the Student, Mentor, and Mentor 2 forms now created, there is one element left uninvestigated. We theorize that the student's progress and experience in the program is heavily dependent on the layout of the entire program. This does not refer to Lego League or FIRST in general, but to how the individual teams are organized. (See Chapter 2, Section 4 for a specific case study on team organization.)

Team organization can vary greatly. A large portion of FLL teams follow the basic model of a parent, a child, and a few of the child's friends working out of a basement or garage. At the other end of the spectrum is a school-sponsored program that has multiple competition teams, each with their own registered number, all funded by the school itself. Clearly students in either of these two examples will have different experiences preparing for the same game. For this reason each team or collection of teams must fill out an Overview Form. The Overview is to be filled out by the head coach, head mentor, program coordinator, or similarly knowledgeable adult on the team. The purpose of this form is to determine exactly how each team works, so later we can try to determine what the environment's effects on mentorship are. In the case of multiple teams under one coordinated program, there only needs to be one Overview filled out for all of those teams.

The final form needed in the package is the waiver. Every person who participates in the survey must fill out a waiver if their responses are to be tabulated. This waiver is necessary due to the collection of names in order to organize the results. The waiver must also fit into the graphical and aesthetic scheme of the form package.

3.3.2 Graphical Concept

With every package containing multiple copies of the five basic forms, the graphical layout needs to be clean and easy to work with. The concept we were working towards is to have a step-by-step process that the team leader can easily carry out with minimal paperwork and hassle.

Every survey element has the same basic format, with a simple heading in bold, under which the person who is to fill out the form is parenthetically indicated. To make them even easier for the participants to process, the left margin has a large title that also says what form it is. For example, the student form has the word "STUDENT" printed at a 90° counter-clockwise rotation up the left edge of the paper. The font for this side-title was chosen very carefully. It needed to be very pronounced, easy to read, but not overbearing on the rest of the form. It needed to look like it was part of the text it indicated, and not just tacked on the side.

The large side banner is what will capture the attention of the readers at the first glance; thus it needs to impress them such that they will want to fill out the rest of the form. Finally, the font, along with the rest of all the forms, needs to be very professional looking. The participants should trust the forms. They will be more apt to fill them out completely and honestly if they get the impression that time and care was put into the design. With all those requirements and intentions considered, the font "Bank Gothic" was chosen to bring the side title text to life.

After the first trial collection day at Mountview Middle School, we encountered a few problems with the form design. The biggest problem was that people kept missing the field they were supposed to put their team number in at the top. The subsequent version of the forms had that prompt enlarged, with a bold box to outline the field. This change was made uniformly across all of the forms, and made the team number much more noticeable.

Additionally before distribution, the online location of the survey was added in a very conspicuous location, just under the team number field at the top of each form. This website contains all of the forms in a downloadable or printable format.

Each form was also color-coded. A big feature of the color-coding was that it made each form was even easier to quickly identify, and more visually appealing. We also developed a cover letter that acted as a key or guide to the rest of the forms. The cover letter is the first thing a participating team will see. It gives complete, but brief, instructions as to how to complete the packet. It begins with the purpose of the survey, then goes on to explain how it could benefit the participant. It also includes basic instructions, as well as a color-coded synopsis of each form.

Originally the colors were chosen almost arbitrarily, but then printing errors produced large volumes of forms with a different color scheme. The cover letter was simply updated to this new scheme and reprinted. The newer, albeit accidental, scheme was actually better once the forms were put to use. It was cleaner and made more sense. Mainly, the waiver was changed from purple to yellow, a useful modification to the most critical piece of the package.

The synopsis of each form has who is to fill it out, what color it is, and how long it will take, along with a very brief sentence on what the form will be asking. The final portion of the cover letter is a short introduction to the researchers themselves, including mention of the WPI system and the IQP. This is concluded with a thank-you to the participants.

All of the forms are available in the appendix of this document. Each component will now be explained in further detail.

3.3.3 Form Review

The Student Form

The Student Form is the core of the survey that interviews the student about the Lego League experience, especially pertaining to mentorship. This form is to be administered to every student in the program in advance of or at a competition. When interviewing the students directly, caution must be used to design a form that will be easy to understand, provide the desired information, and be within a reasonable length, so as not to bore the student. If the student is bored or overwhelmed by the form, then the probability of accurate responses will go down (See "Data Exceptions", ch 4). For that reason, the Student Form especially must be clean, streamlined, and concise. We need to extract important information without seeming overbearing to the student.

The first section of the Student Form is a simple identification heading. The student's name, age, and gender are requested, along with their Lego League experience and roll on the team. The experience question asks for how many years of experience they have, including the one they are currently in, which implies a default of one. The maximum expected value is four, if the student is in eighth grade and has been active since fifth. This is essentially the maximum age span allowable by FIRST in the program. The roll on the team question is also open-response, where expected results are 'programmer,' 'researcher,' 'builder,' 'operator,' or any synonym. This information will be useful in categorizing the data, but the names will be stripped off during analysis. Having the student put his or her name is only a mechanism to match this form up with the rest of that student's data, and that student's team data. Once the associations are made, each student is represented by a unique ID number and will not be reflected back on that student or team in any way.

The next section of the form is a checkbox matrix. Here the student self-reports on their ability to program, design and construction, and research. Each of these "tasks" is a fundamental skill needed for successful participation in the Lego League competition. The available levels for each task are 'Beginner,' 'Intermediate,' 'Advanced,' and 'Did not attempt'. This data is also to be used to find basic trends, arguing that, for example, programmers may have different mentoring preferences than builders.

Question 6 is the most important select-a-response question. The question is simple: "How helpful is your mentor?" The purpose of this question seems evident. The student's opinion of the mentor's helpfulness is a prime measure of mentor effectiveness. These are easily represented by the original responses: 'couldn't have done it without them,' 'helped some,' 'was not helpful,' and 'did the work for me'. The last response had another purpose: determining if the mentor did the work *for* the student instead of guiding the student to discover on it's own. This issue is extremely important to this study because it voids any actual learning that the student should undertake through the course of the robot development. However, the mentors cannot simply be confronted and blatantly asked if they did the work for the students. That would, at first look, be insulting. Beyond that the mentors would be extremely unlikely to answer that question honestly. Once a survey participant intentionally misrepresents himself on one question, he is more likely to do the same on other questions.

One more response was added to Question 6 after testing the form on a real, live middle school student. The volunteer test subject was asked to review the form as if he were an active Lego League participant and find any flaws that we overlooked. The specific purpose of this was to ensure that the questions were concise and clear, especially to the average middle school reading and interpretation level. The primary comment about the student form that the test reviewer gave was that there was no option in the Helpfulness question for a mentor who simply sat back and watched. For that reason, the response 'just supervised' was added to be the third of five. It was placed in the middle because it is the most neutral on the scale of mentor helpfulness, where at the bottom the mentor does the work for the student and at the top the mentor was critically and positively helpful.

The last multiple-choice question is Question 7 that asks what the student's preferred mentorship method is. These responses are general categories of mentor habits and trends that we observed through our experience with Lego League. There are four basic strategies: 'gives examples,' 'shows solutions to hard problems,' 'forced to learn on own,' and 'provided any solution when asked'. These basic four mentor types were selected because they cover pretty much every mentorship method, while facilitating the student's thoughts as to which is most 'desirable'. Any of the responses is to be expected from any student, as is variation within team and within category. The data from this question will be used later to see any character patterns between preferred mentorship methods and another category, the student's roll on the team.

Question 8 asks if the mentor(s) helped the student analyze game strategy. This question is important because the strategy of the team determines how the entire development of the robot is to be structured. It also defines the thought patterns that must be followed to successfully design the machine and operating instructions. Having the mentor assist the student with strategy helps the student to concentrate on the development of the robot and program, while sticking to the plan given by, or designed with, the mentor. In contrast, if the student is to analyze the game and come up with a strategy on his/her own, then the student will have a more in-depth understanding of the game and the development process. It is very possible, however that this could be too much for the student to absorb, and may result in a less enjoyable experience overall. Whether or not the student worked in the pre-season to prepare for the game very likely impacts the overall enjoyment of the season as well. This pre-season information is obtained from the Team Overview form, with which the student is associated.

The last two questions are open-response, where the student is asked if there is anything else they would like to comment on regarding interactions with the mentor or the other students on the team. These questions could provide subjective insight into the experience of the student, which is very important to consider. Conclusions as to how students react to each other and to mentorship cannot be based on numerical analysis alone, and this small invitation to the student to share their thoughts is the best way of generating a more "human" look at the program.

The Mentor 1 Form

This purpose of the Mentor 1 Form is to get some information about the mentor him/herself, including experience, tact, and personal reflections on instruction in the Lego League environment. The first two questions are basic statistical elements asking for age and years of experience in mentoring. The following questions attempt to categorize the mentor.

The first substantial question is number three, which asks how familiar the mentor was with the subject matter before starting. It has been shown in many previous research studies (Literature Review (Chapter 2 Section 3)) that knowing the subject matter is very important for effective teaching. The possible responses for this question are a range of four elements: 'Never seen it before,' 'Unfamiliar,' 'Familiar,' and 'Formally Educated'. Any of these responses are suitable according to the definition of a FIRST mentor. However, research shows that a teacher must be well educated in the subject matter in order to teach it effectively.

Question 4 asks if the mentor has any relationship to any member of the team. This is to detect parents, siblings, and other such relationships that could affect the natural mentor/student interaction. If the mentor is, in fact, related, then the next field asks for the relationship.

Question 5 asks what duties the mentor performs on the team. This question, in a way, helps to define "mentor." Many mentors have specialties when teaching, and others (who typically fit the 'coach' description) don't teach at all. Question five inquires what specialty the mentor has, including the checkbox-responses of Programming, Construction, Research, Administration, and Other. The latter of those asks for a brief explanation with an open response field if selected.

One simple, but very important question is whether the mentor works with the students prior to the season. This information is also determined in the Overview Form, but asking each individual mentor will provide more point statistics to reference against. Question 6 is that simple question, where expected responses are yes or no.

Question 7 is a bit more pointed, asking how many hours per week the mentor works with the students. The Overview Form also provides how many hours per week the program meets, but this question determines the individual mentor's level of participation, which may be used to explain student commentary for that mentor.

Question 8 is paired with Question 7 of the Student Form. It asks what mentoring strategy the mentor uses. There are seven checkboxes, and the mentor is asked to check all that apply to them. Responses are: 'Teach by giving examples,' 'Relate project-specific problems with known solutions,' 'Show students solutions to hard problems they encounter,' 'Force the students to learn on their own,' 'Answer questions only when posed,' 'Provide information before it's needed,' and 'Give goals to work towards'. These are the basic styles of mentoring, and the vast majority of mentors in this context, or teachers in general, will fit in to one of these seven models. Each offers a different approach to mentorship, some of which are more beneficial to different students. There are no responses that are specifically better or worse than others. It is the effectiveness of each of these methods that is being investigated by this survey.

Question 9 asks if the mentor analyzes strategy with the students. This is paired with question 8 of the Student form. The final question for the mentor is an open-thought-response asking if there is anything else they wish to contribute regarding their experience as a mentor.

Mentor 2

The Mentor 2 Form is a basic feedback mechanism to test the student's self-report. A coach or mentor is asked to fill out a small questionnaire about each student that reflects their ability in the three major categories, as well as the student's contribution level to the team. Three student evaluations fit on a single sheet of paper. Each one has an ability matrix that matches the one on the Student Form and a checkbox question. The responses to the checkboxes are: 'Principal Contributor', which is a student who develops ideas and works towards executing them; 'Secondary Contributor,' a student who performs their assigned tasks and occasionally creates ideas; and 'Observer,' who spends the majority of their time watching and occasionally performs tasks when specifically asked to do so.

The information in the Mentor 2 Form was originally designed to validate the student's self-report, but it could also be very useful in finding out how the mentors work with, and think about, their students. It is not reasonable to assume that the mentor is infallible for the purposes of this study. They are just as subject to opinions and interpretation as the students are. For example, it is very possible that the mentor's gauge of ability will consistently be higher or lower in a certain area, most likely a result of their extra familiarity or unfamiliarity with that area.

Overview

The Program Overview Form is intended to see how teams compare to each other on a very general level. Some teams have school funding, support with computer labs, and teams of knowledgeable mentors. Other teams, in contrast, consist only of a parent, a child, and a few friends in a basement or garage. These teams clearly provide a very different experience for the students, and it is the purpose of the Overview Form to determine how students respond to different types of team organization. The form itself has only six questions about the program structure, but when linked to the students in that program, the results can potentially be seen. A head coach, mentor, or other program leader is asked to fill out this form.

The first question asks the operational size of the program. That includes the total number of students, the total number of mentors, and the number of students with whom they normally work. The last part implies the level of real, interested participation among the total accessible student body.

The second question asks how many weeks prior to the season the program begins working with students. Preparing students for the challenges of the season beforehand could provide a substantial advantage to the students, and the length of time during which the program ramps up to the season kickoff could be used to see trends against the other data. Reasonable responses should fall between one and four weeks, with zero being a perfectly acceptable answer.

Question 3 asks "Where do you meet?" The actual productivity environment can affect students greatly. In this question there are four checkboxes responses, plus an "Other" with a blank line to fill in. The choices are Home, School, Public Building (such as a library), Private Facility, or the Other.

Another important issue when considering productivity is how many computers the teams have at their disposal. The two major sides to robot development are the hardware and software. The physical robot can be built under almost any conditions as long as there is a kit of appropriate parts available. Only one robot can be submitted per team, so generally there will be only one kit per team. The robot's functionality, however, depends on the writing of multiple programs, which requires a computer. Having multiple programmers working at once is a statistic that cannot be ignored, and Question 4 asks what the maximum of that is per team. This number will be compared against how many active students the team has (Question 1) to determine a student to computer ratio.

Question 5 is an open-response question asking what is unique about the program. This gives the program leader the opportunity to explain something special about their program. Every Lego League team is different, and this can provide a better understanding of that individuality.

Question 6 asks if the team has a source of funding other than the members and parents of the team. This question can immediately segregate results, because it is generally thought that more funding results in a better educational program.

Waiver

The most critical piece of the form package is the Waiver, a half-page permission form that allows the participant's data to be used in the tabulations. The top of this form has a short paragraph describing the purpose of the survey and what is required of the survey participants, including a very brief mention of all the forms. This is a very compressed version of the Cover Letter, but it is necessary to explain what the participants are agreeing to on the waiver. It states that all personal and team data will remain completely confidential, and that any questions or concerns can be directed to the research team by email.

The bottom part of the waiver is the contract stating that all personal information will be kept anonymous, that the results have no affect on FLL standings, and that the survey is completely voluntary. With that, the participants must sign and date the waiver, or have a parent sign for them if they are under the age of 18.

The majority of students participating in this survey will be under the age of 18, and not all of them will have a parent present at the competitions where the forms are to be collected. That is the main rationale for having the forms sent to the teams before the competitions: to give them time to send forms home to get them signed by parents.

At the very bottom of the waiver is a checkbox to indicate if the participant wants to receive the results when the research is complete. That question was placed on the waiver because it is the only form that must have full name and team number on it for each person, so it will be the easiest to use to find the person afterwards if results are requested.

3.4 Collection

Collecting survey data from the FLL competitions followed a simple process, before, during, and after the competition. These steps are categorized as pre-competition, at-competition, and post-competition. By following these steps, reliable data was gathered without causing inconveniences for team members at the competition itself. This lack of annoyance made people more willing to fill out the survey, and increased the accuracy of their results.

At each competition different measures were used, with different effectiveness. The Robonautica Tournament held at WPI provided a competition venue for the teams from western Massachusetts, while the Quincy tournament was held near Boston for the eastern Massachusetts teams. The Robonautica tournament was held in mid-December, and the Quincy tournament was held in late January due to postponements.

These measures were based on a trial collection day at the Mountview competition. This competition is traditionally the deciding point for which teams move on in the first round of competition. Many of the innovative measures used later arose from this test collection. Some of these innovations were the reward system, the creation of a team uniform, bringing pens with us, as well as learning how to present certain concepts which occasionally confused the students.

It was also at this point when the Turn-In database was created. This database was a very simple way to track who had turned in which forms. It was accomplished by using Microsoft Excel to make a spreadsheet of participant names vs. all the possible forms. As surveys were collected, new names were added and sorted by team number. This provided a quick way to look up the state each team was in, allowing a relatively painless check-up process in which participants missing certain items were approached and asked if they would be interested in completing them.

3.4.1 Robonautica

Robonautica was the primary source of survey data, and was originally intended to provide all necessary data. Preparation was much more complete for this competition, and the competition as a whole was much more productive.

Pre-Competition

Following completion of the survey forms, group attention was turned towards preparations for the data collection. The first step was to approach the competition director and attain permission to collect the data. The director was easy to get in touch with because of prior contact on the Mountview FLL teams. This friendly contact allowed many tasks to be quickly and easily performed. This is in contrast to the Quincy event, at which competition was established very late and no true preparatory tasks were performed.

To minimize the time taken away from teams at the event itself, surveys were produced and packaged with the Robonautica information packet. This gave the teams time to fill out all the necessary forms before the competition, or at least look them over so the forms would take less time to complete later. During the survey form production, many extra forms were produced to be handed out at the event itself. The forms were also placed online, and links to this online version were distributed along with the information packets. This completed all of the paper-based preparations for the Robonautica event.

The next step was to set up the competition venue and increase awareness of the competition staff. To accomplish this, group members attended set-up meetings and became well versed in the layout of the venue. The survey table was designated a space on the third floor of the event, out of everyone's way except for those teams going to present the technical aspects of their robot designs. The theory was that the teams would queue up at this point for a ten minute wait, with nothing to do but complete the surveys. However, due to the hidden nature of the table, it was decided to place posters directing the teams to the survey Turn-In point. These posters used official competition backgrounds and fonts in order to blend in with the surrounding posters, but were plotted much larger and at higher quality to increase viewing range. Candy and toys were purchased in order to provide incentive to students who filled out forms. Pens remained after the test collection day, so no new pens needed to be acquired at this time. Having gathered the necessary materials, created the forms, and begun the surveying process, preparation for the event was complete and the collection phase for the Robonautica competition could begin.

At-Competition

Like any other FIRST competition, Robonautica is a fast-paced, noisy setup consisting of audience noise, loud music, and the general yelling of excited middle-school students. This is what made the survey Turn-In Point location very advantageous, as it was situated in one of the few quiet areas. The table was easily located by most of the teams due to the posters;

however, some teams handed their completed packets to the people at the registration table, from whence they disappeared for a few days.

Upon arrival, the survey table was quickly set up and staffed by the IQP group members. The first half-hour was hectic as teams passed in the completed survey packets they received by mail, beginning the official collection. At this point, a general scheme for the rest of the day was devised. Two group members would be in charge of data handling, while the third would go on patrol to convince other teams to participate, as well as to find people who were missing certain forms. These missing forms were isolated by the data handling team, who remained to guard the table. One member kept busy by taking forms from teams and trying to organize them for easy location later. The other member would take the forms after they were organized and enter them into the Turn-In database. This division of labor provided an effective means of data collection and organization, preventing significant confusion among the collection group, as well as among the teams.

The one time this pattern of activity was altered was during the hour-long lunch block allotted to all teams. At this time, two of the surveyors moved into the Campus Center to approach the teams while they ate. This was minimally effective, collecting a total of two surveys. However, it did raise awareness among the teams, leading to the collection of more surveys later in the day.

The afternoon time block was very similar to the morning block, only slower. Most of the teams willing to spend the ten minutes to fill out the forms had already done so at this time and the technical judging was coming to a close, stopping the flow of teams by the table. At this point, many of the missing forms were hunted down on a student-by-student basis through the use of the Turn-In database.

Unfortunately, many people were unwilling to participate for reasons not known. Time may have been a concern, although we addressed this issue by stating in the survey introduction how quickly the forms could be completed. Certain team members' parents would not sign the waivers for their children, thereby preventing us from obtaining usable data from them, and one or two coaches barred whole teams from participating. Until this point, the waiver was looked upon as a necessary formality but, as time went by, it became a larger and larger hindrance to gathering large quantities of usable data. The waiver issue is discussed in greater detail later on.

About 30 percent of the student forms collected were unusable due to the lack of a signed waiver. The waiver problem was even more pronounced among adults who, by not signing, implied a lack of consent and became unusable. The day was a success, but not as much data was gathered as desired. The Quincy tournament was then selected as a follow-up in order to get more usable information.

Post-Competition

After the competition the forms had to be organized so that we could eventually run statistics. We found the need for an additional database with a different purpose. After some debate it was decided that we would create a database using Microsoft Access and input all of the data. This database would be very user-friendly for the input of the data. After completion, it would also be easy to export data to a more powerful statistical program. Since the Overview Form needed to be examined case by case the database did not include it. All of the student data from the Student Forms and the Mentor 2 Forms were put into the student section of the database.

Before entering any data, all of the forms needed to be organized. All waivers were attached to the corresponding Student Form or Mentor Form, and all mentor 2 forms were attached to the corresponding Ftudent Forms. This made sure all of the information for each individual was together, and to make sure we did not break any ethical obligations by using data that we did not have consent to use. When entering information, there were a few bugs with the database that needed to be worked out. Before this was done, some comments were abbreviated or not completed but, since we will individually look at the comments that was a temporarily acceptable solution. After entering all of the data, the forms, the

Turn-In database, and the Access database were all compared. At this point, any data that had a waiver was entered regardless of what it said, because no consideration was given to significant data.

3.4.2 Quincy

The Quincy Tournament was not originally planned as a data gathering day, but was added after Robonautica to get larger amounts of data. The last minute nature of this decision to attend prevented much of the early planning required to get the best results. The distance to travel to Quincy was also an issue, as the survey group was only able to visit the venue the day of the competition. Instead of the thorough measures used for Robonautica, the following procedure was followed.

Pre-Competition

The extent of the pre-competition planning consisted of two items. The tournament director for Quincy was contacted via email, and permission to administer the survey was obtained. The second step was to make sure enough copies of the forms existed to be filled out on-site, as there was no time to mail out packets. Without the preparatory work, many of the teams felt too busy to be bothered with the survey at the event, and many fewer results were gathered throughout the day, than were gathered at Robonautica.

At-Competition

Setting up on the day of the competition proved easier than anticipated, and a table was quickly commandeered in the middle of the team "pit" area. This central location was easier to find than at Robonautica, but made policing the teams as they came to fill out the forms much harder. To fully advertise this location, the posters from Robonautica were placed around the area, directing the teams to the survey table.

The Quincy tournament contained far fewer teams than Robonautica, so the table needed only one person to fully staff it. This allowed the other two members to patrol the area and convince other teams to participate. Methodically asking each team in turn provided the best results for the day, with approximately half of the teams taking part.

The rate of rejection among the Quincy teams was much higher than that of Robonautica as well. One theory is that this may be due to the lack of preparatory work done beforehand to prime the teams. The other theory is that the teams had already been forced to participate in a Brandeis survey. In order to participate in the competition, all teams *must* participate in the official survey, after which many teams refused to take part in another. The upside of this other survey was that we made contact with the survey representative at the competition, who thought that our unofficial survey was very well designed.

Data tracking was accomplished by using the Turn-In database again. In addition to tracking the new students at this event, old students who attended both competitions were also found and surveys completed. By the end of the day forms from 30 more students with valid waivers were collected. This rounded out the number of good responses to over 100 students. New mentors were also gathered at this event, bringing the total number of useable mentors above 30. With this amount of data, it was thought that significant statistical analysis could be conducted, leading to the required conclusions and, eventually, the mentoring handbook.

Post-Competition

After the Quincy tournament, the organization was much easier. The majority of the data was entered in both the Access and Turn-In databases onsite. All of the forms were organized as they were handed in so, after the competition, the only work left to be done was checking over everything that was entered.

Chapter 4

Results

Statistical analysis was the primary means of converting the survey data into the information required to write the handbook. To perform this analysis, a program titled SPSS 11.5 was used. Due to the nature of the survey itself, and the desired results thereof, statistical analysis began with the student based information, obtained from the Student Form and the Mentor 2 Form. The data was originally data based using Microsoft Access. This database was then exported into SPSS for analysis.

At this point, with the data freshly copied over, certain alterations were made on a case-by-case basis. These alterations were mainly error checking, fixing typos, and the like from the data entry process. Many of these data entry mishaps were due to the use of Microsoft Access as an intermediary program; in many places we asked for Boolean results, and if the question was not answered this came across as a "false" instead of as missing data. Manually going through the forms again and removing the incorrect entries from the SPSS version of the data solved the missing-data problem. After this basic correction was completed, certain variables were expanded into a useable format. For example, the role the student played on the team was broken into six different categories in which the child could either have a one or a zero. This allowed for numerical tests against these fields, which was not possible against the original string format. During this process, numerous joking comments were discovered as certain student played more interesting roles on their teams than was expected. Examples of these roles were the "team energizer" and the team "3". These extra roles were categorized simply as team member, the default value for any student who participated in the survey. Also during the data cleanup was the removal of all students who willingly falsified information, as none of their information could be trusted. An example of falsified information was the student with the age of 150 years. All alterations, either for incorrectly entered data or variable changes decided upon at this point, were recorded and dated in a change log kept digitally with the database.

Following the initial data cleanup, the first level of the statistical analysis took place. Not knowing for sure which variables were related or how, the first test run was a cross-tabs test implementing the chi-squared statistical method. This test provides general information on the confidence interval in a relation between two variables. By definition, a relation is significant if the confidence interval is .05 or less; the lower the number the better the correlation. Many of the expected relationships were noted at this point, along with some that were rather unexpected, as well as certain items that were notably absent.

It was expected that the mentor reports of the students' abilities would follow the same trend as the students' self reports as, hopefully, the more skilled would have been reported higher on both forms. This, however, was not found to be the case in all of the skills listed. While the programming and research skills seemed to have an accurate association from these tests, the assessment of mechanical skill differed between the students and the mentors. It was found, during a different set of tests, that the mechanical skill reported by the mentor was influenced heavily by gender, while the student report was not. This has some very serious implications for the mentors' perceptions of their students, and will be further discussed in the handbook and results sections (see Chapter 5 Section 3 and appendix A).

Certain other relationships became apparent at this time as well, and it was these important realizations that led to the next steps in data analysis. Based on past experiences with the Mountview FLL teams an even grade distribution was expected. However, it was found that, in most teams, the students involved are from very restricted groups. Teams consist primarily of one age group from one school grade, very likely a group of friends who all joined the team in order to have something to do together after school. There is no conclusive way to examine the reasons for this grouping; however, it is apparent that friends tend to stick together, especially at that age group. The same is true of gender, with single gender teams being much more common than mixed gender teams, and all-male teams outnumbering female teams. This tendancy for similar students to group together provided reason to examine certain aspects of the students reported values by team rather than by student. This break-up of information by team would allow us to see the trends inside each team and across teams, which leads further toward isolating the differences between teams and the effects of these differences.

In order to break the data up by team, a new way of dealing with each variable was required. It was decided that simple state variables such as "being a programmer" or "the mentor helped us with strategy" could be best represented by a percentage, so if three out of four students on a team said they were researchers that team would get a 75their researcher category. Alternatively, variable response questions such as age and skill in the different skill groups was converted to an average. A new data field was also recorded in the new team separated database to allow us to keep track of how many students were originally on each team. This number represents only how many usable surveys were recieved from each team and has no bearing on the overall team size. As a side note, there were many teams from which only one usable student data case was available, and these single member teams were not included in the analysis of the team separated database as they would very easily skew the statistics.

The Mountview Lego League teams were also discarded during this step in the analysis for different reasons. The Mountview program consists of five student groups or teams but only three officially registered FLL team numbers. This means that each team gets a chance to use the team numbers at the differing competitions. The error here becomes obvious. Female students are found mixed into the male teams due to the repeat team number use. Instead of lumping the students into one large team for data analysis it was decided that the team should be excluded from the team database entirely. Instead Mountview will be looked at in great detail as a case study based on information gathered prior to the survey distribution.

Running the general cross-tabs analysis to find significant relationships on this new view of the data demonstrated some very important relationships that severely impact the way that mentoring should be handled. These relationships lie in the students' desired mentoring strategies when compared with the students' roles on the team. It was initially thought that certain groups of students would prefer different mentoring strategies; these groups were thought to be defined by age, gender, prior experience, and other variables that define the team as a whole. Instead, it was found that the preferred mentoring tactic is a result of the role each student plays on the team. Teams with a high concentration of programmers prefer different teaching approaches than the more mechanically minded teams. This is an important distinction to make, as most mentors have the least experience with programming and it is commonly looked upon as the hardest skill to teach. By looking at what the actual programmers prefer, it is possible for a mentor to become a much more useful tool in the students learning (for more information on this topic see the Conclusions and the handbook (chapter 6 and appendix A respectively)).

The other important relationships discovered during this analysis phase were the relations concerning role on the team. A relation was found between the concentration of programmers and that of operators. In our experience, it seems that many teams feel that those who write the code are the best suited to operate the robot while it is using that code. Another relationship to consider is that teams with a higher concentration of experienced members reported a higher concentration of researchers.

To continue to view the data from different standpoints, it was decided that the mentors should be analyzed as a group to see if there were any trends there. Then we placed their data in the team database to see how the individual mentors affected the results shown above. Before the mentor data could be looked at, it needed to be debugged in the same way as the student information. Missing data needed to be confirmed, typos corrected, and comments broken into numeric fields.

After setting up the mentor database, basic statistics showed that there were neither more male nor more female mentors, with 13 males and 12 females. Gender does not play a role either in experience in FLL or in familiarity with the material to be taught. This is slightly incongruous with the fact that mentors report a higher mechanical aptitude in the male students (as discussed in Chapter 5 Section 3). The mentor age range was, on average, late 30s through late 40s, with the occasional high-school-aged mentor. Most mentors were parents of a student on the team they mentor, which explains the age distribution range and the gender equality. The average hours per week of team related activity usually lies within the range of 2-5 hours, although there are a few mentors who report they contribute 10-20 hours a week.

The teaching methods of the mentors were also examined at this point. By choosing from a list of pre-selected archetypes in teaching it was seen that there were a few categories that were much more popular as instruction methods. The vast majority of mentors teach by example, and many mentors also use related solutions and question answering to continue teaching. The second most popular teaching method is to force the students to do it on their own. This could be to force learning, or simply that the mentors do not know the material well enough to answer all questions as they arise. After running this initial descriptive statistics test the mentor results were added to the team database, providing further insight into the correlations between mentor dependant information and the data gathered from the students.

When attempting this addition to the database, it was discovered that due to waiver incompletion and lack of mentor responses, only five teams had data from both students and mentors. This implies that any significance found running cross tabs on this data may not hold for the entire set, and any relationships will be much harder to isolate with only the five data points. In order to statistically show that these results, when found, would hold for the entire set, a one-sample T-test was run to determine the mean variance in the mentors. If the mean variance is low, then the mentors as a group are very similar and relations between mentors and students will follow this similarity. Unfortunately, the T-test results show that not all mentors follow an average type, and the results of analysis cannot be said to cover the entire grouping.

Running the cross-tabs on the mentors and students together provided very few significant relationships, which is liley due to the low number of samples. Primarily it was shown that as mentor involvement (helping with programming, research, construction, and participating in the preseason) increases, the number of students who claim operator and leader status increases also. While this relation does not necessarily apply to the group of teams as a whole, it is significant in these groups to show that the level of team dynamics and the diversity of roles on a team increase with mentor participation.

Chapter 5

Analysis

In this chapter we will discuss in greater detail the responses from the survey. This will include both a look at the relationships which were unexpected as well as the lack of certain expected results. In order to easily demonstrate the data collected, graphical representations have been created. These graphs and charts accurately show the important finding used to draw the conclusions necessary to create the mentoring handbook.

Following each graph will be a few paragraphs explaining the graph and its implications. Theories behind the findings will be introduced at this point, along with possible points of error. While these theories may or may not have an impact on the content in the FLL handbook, it is very important to understand the reasons behind the relationships found.

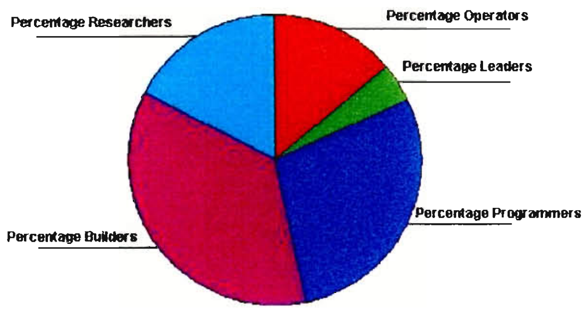
There are three primary categories in which the topics to be discussed fall. Distribution of labor describes the breakdown of the students' roles on the team. This division of labor is one of the crucial steps in forming an efficient team, and it is discussed in great detail in the handbook (Appendix A). The second important topic is mentoring strategies, or the teaching methods the children prefer. This was found to be heavily dependant on the role of the student on the team, and will be analyzed as such. Lastly, the mentors are analyzed. This analysis includes both the teaching strategies most commonly implemented, as well as a very important look into the differences in perspective between the students and mentors.

5.1 Division of Labor

This section deals entirely with the breakdown of the jobs on the teams. In order to perform all of the necessary work during the FLL season it is important to specialize the students into a few fields. These necessary fields include researchers, builders, and programmers. Without all three of these jobs a team will not be able to successfully compete in a regional event.

The remaining jobs are leader and operator. This is an extra level of separation among the students, and the majority of leaders and operators are also programmers, builders, or researchers. A team can be very successful without these positions but it is interesting to see the breakdown of the teams including these fields.

Figure 1: Chart of Team Roles



In order to visualize the separation of labor more effectively, the above pie-chart was created. This chart was done by averaging the percentages of the different jobs on each team. These average percentages then became the values used to create the pie-chart as seen.

As stated above, the roles of builder, programmer, and researcher are the most commonly reported results, and therefore take up the majority of the chart. Leader and operator were unexpected values for the role, yet still take up a sizable percentage of the students.

Based on this chart, and the experiences on the Mountview team, we are able to form some ideas about the nature of team labor separation. These ideas are the first step in drawing the conclusions about team dynamics necessary to write the handbook.

First we will talk about leaders. Leadership positions on teams should be very limited, and this is reflected in the small percentage of students who report themselves as leaders. If leaders outnumbered the followers on any team, this could be a cause for concern. However, the graph shows that the leaders take an appropriate portion of the overall labor force. It is also important to note that leaders are only those who reported themselves as such. This means that any number of children could have claimed to have a leadership position, yet only a small number did.

The next role to discuss is the operators. Many teams do not have defined operator positions, and many force all team members to participate in this role at one point or another. Most effective, however, are the teams who allow certain students ample practice time with the robot and the field, allowing for quick response during competition. This group of designated operators is normally a small percentage of the team, and this can be seen in the chart above. If all students were operators, this slice would overpower all other positions, yet it remains a relatively small portion of the group.

Builders, programmers, and researchers are all necessary members of the group. Thus, they take up the majority of the teams' labor distribution. Researchers take up the least amount of personnel of the three primary jobs and is still seen as a secondary aspect of the competition. Research will not produce a robot, nor will research make the robot do what you want it to do, and making the robot play the game is the point for most of the students who participate in FLL. For many students, the very word "research" has evil connotations, and many adults still dislike to do research projects. It is this lack of enthusiasm that makes the researchers the smallest group of the three.

Programmers are the second most populous type of worker. Here are some of the possible reasons for this positioning in the overall set-up of the teams. As briefly mentioned, programming is one of the two areas that directly contribute to the robot performing well. This allows the students to get excited about this area due to its importance. Another factor to which we can attribute the large percentage of programmers is the use of computers. Many people interested in robotics are more interested in the electrical, logical side of robotics than the mechanical aspect. The last reason to become a programmer is that many teams assign extra members the task of programming if the construction team becomes too large to function well.

On the other hand the programming group on each team is not the largest, for a couple of reasons as well. First, and most importantly programming is very hard for many of the students, due to either a lack of instruction or just the newness involved in writing code for the first time. The second limiting factor for programming is often the number of computers/programs available for concurrent work. On many teams, there is only one computer on which to program, and this means that only one program can be worked on at any given time. Also, the Lego robotics brain can only store a maximum of five programs at any time. These three factors decrease the number of programmers who can be productive at any given moment.

The most popular choice of occupation on FLL teams is that of the builder. Similar to programming, construction is one of the two areas which directly contribute to the completion of a viable, competition-ready robot. Also, construction is commonly seen as simple compared to programming, and that draws many of the students who do not desire the challenge inherent in learning to program. The fact that builders are the only ones who get to "play" with Legos on a regular basis also contributes to the appeal of being a builder. The only factors that prevent everyone from being a builder, at least part of the time, are the requirement of completing the other jobs in order to succeed, and the natural limit on how many hands can be building the robot at once.

With the above reasons taken into account, we can rationalize the proportions seen in the pie-chart very easily. All of the slices seem to make sense, even to those who have never been in the program before.

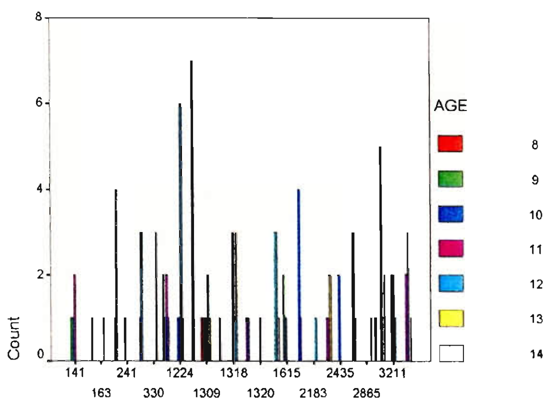
Now that we have covered the basic layout of the positions on a team we will further examine any relationships between these roles. Based on the cross-tabs tests performed and discussed in Chapter 4, there are only two significant relationships in the roles on the team; the concentration of programmers vs. that of operators, and the percentage of experienced members vs. the percentage of researchers.

There is a noticeable increase in the reported percentage of operators when the percentage of programmers is increased. This shows that teams feel that programmers are better able to operate the robot.

There is also a relationship between the average experience of members on the team and the number of researchers on that team. As experience increases, the number of researchers on a team also increases. This is because team members who have gone through the program before recognize the need for good research in order to develop an understanding the material presented. They also know the importance of competing in the research segment of the competition.

The last segment of team make-up which we have found to be significant is the grouping of middle school students by age. Instead of the expected random distribution, it was found that teams tended to be only one age group. This trend can be seen in the following chart.

Figure 2: Trend of Age Grouping in Teams



This graph shows each team's age distribution. If the age distribution was either even or random we would see many bars of the same height with few outlying tall bars. Instead, we can see one spike in almost every team. Each of these spikes represents an age group

teacher who employed the same methods they do not prefer now, they would still not desire these methods in the future. However, for the majority of the choices provided, a general trend can be established for that category of work. If the majority report they would like the mentor to "do it for me," that is very different from "learn on my own." Even with different teaching methods, these preferences are important.

In order for this role-based analysis to be conducted over the whole group of students simultaneously, it is first necessary to show that all teams are similar in their preferences for all four categories. This similarity shows that the effect of the individual mentors on a team's preferences are negligible. In order to make this conclusion, each preference was graphed across the teams individually. The following four images show this distribution across all of the teams, and the similarities provide evidence that the mentors did, in fact, have little influence on the overall preferences of a given team.

Figure 3: Teams' Preference to be Given Examples

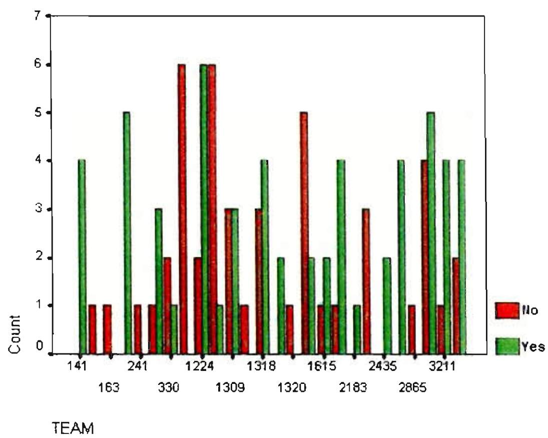


Figure 4: Team Preference to be Shown Solutions to Hard Problems

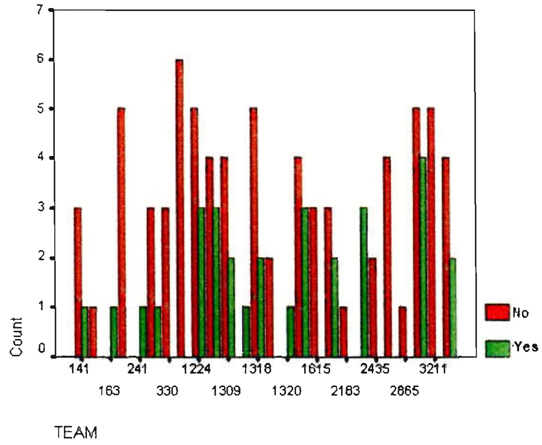


Figure 5: Teams' Preference to be Forced To Learn on Their Own

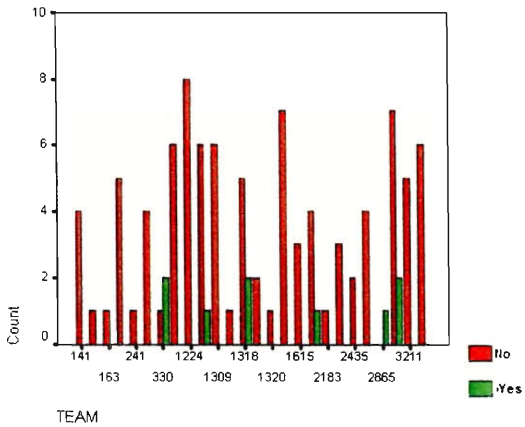
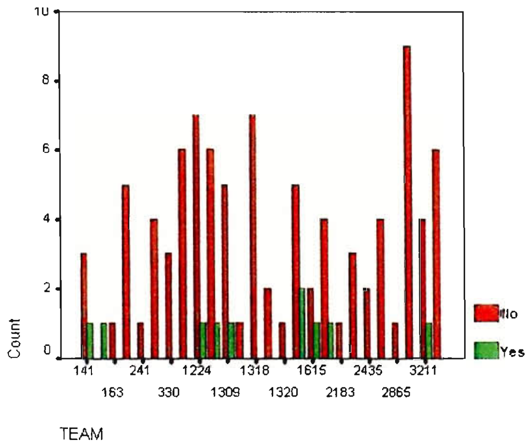
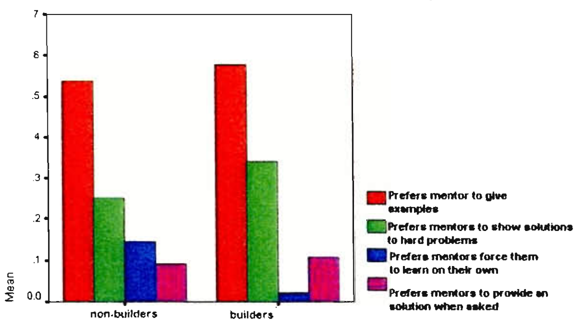


Figure 6: Teams' Preference to be Provided to Any Solution When Asked



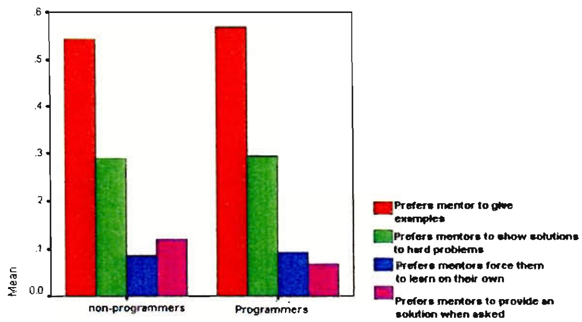
Now that the teams can be analyzed simultaneously instead of individually, we can begin the role-based analysis. Builders are the most populous type of worker, as discussed above, and are also the easiest to draw conclusions on regarding their preferred mentoring strategies. A graph showing the number of students who prefer each teaching method, split by either builder or non-builder status, gives a quick view of the preferences of this group.

Figure 7: Builder Prefered Mentoring Style



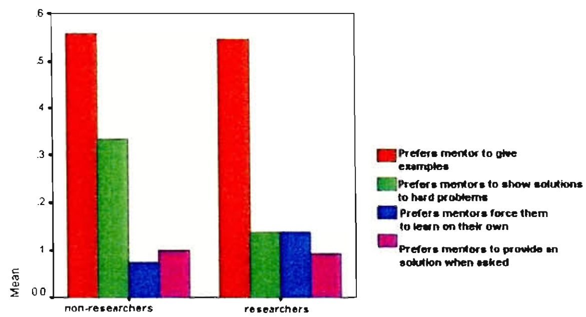
In this chart, it is apparent that many fewer builders prefer being forced to learn on their own when compared to non-builders. Instead there is an increase in the number of students who desire the "shows solutions to hard problems" method. This means that the mechanically minded students do not enjoy learning how to do everything on their own, making the mentors' job of teaching significant in this group.

Figure 8:Programmers' Prefered Mentoring Styles



Programmers are similar to builders in many ways; however, they do not show the same change in preferred technique. In the programmers preference chart across all students, no significant change is seen, showing an equal preference for each strategy in programmers and non-programmers.

Figure 9: Researcher's Prefered Mentoring Styles



Researchers do have a significant change in preferred methods, and it is opposite that of builders. Instead of being shown solutions to hard problems, the researching students prefer to be forced to learn it on their own. This makes sense, as research is often an individual pursuit, and one that is not very easily taught.

Based on the above trends in teaching preferences, important decisions can be made as to the best way to teach team members. These conclusions and further rationale behind these decisions can be found in Chapter 6.

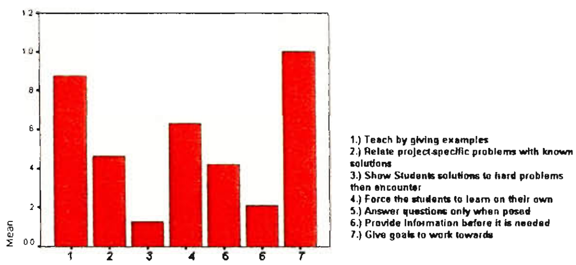
5.3 Mentor Analysis

Using the data collected from the mentors, important observations can be made about the mentors themselves. Most important of these observations involve the teaching methods most commonly used by mentors at this time. Another area of interest is the comparison of the mentors' on the student versus the students' self-reports. Lastly, we will examine in detail any differences that may exist between mentors, as this may impact the mentoring experience for each group.

Instruction Methods

In order to analyze the teaching methods of the mentors, a chart was created showing the count of how many mentors reported the use of each mentoring strategy.

Figure 10 : Overall Mentoring Stratgies Used



Clearly there are three preferred mentoring strategies, taught by giving examples, force to learn on own, and giving goals to work towards. Due to the nature of the question, each mentor may report more than one strategy if they used more than one, and this leads to a good deal of overlap in the method selection data. Almost all mentors reported giving goals to work towards, in addition to one or two other strategies. This means that the two primary types of teaching are showing examples and letting the students do it all on their own. Both of these methods can be effective, but the student data shows a lack of interest in the "forced to learn" method.

One possible reason for the above distribution of mentoring methods is a lack of experience. Although no significant relationship was found between experience and mentoring strategies, it is possible that mentors who do not feel comfortable teaching the material instead force the students to learn it on their own. It is also possible that the mentors are perfectly comfortable in a teaching role and still choose to force the students to learn it themselves. Whether instructed or not, the children will eventually learn the material, but we have found through our experiences that it is more efficient for some initial teaching to be given. Once the broad concepts are understood the fine points are quickly mastered, with or without detailed instruction.

Mentor vs. Student Point of View

One of the most important findings during this research is the differences in perception between the mentors and the students they mentor. This distinction can be seen when comparing the mentor-reported skills and the self-reported skills of the students. Initially, these questions were set up in parallel to ensure that the children were self-reporting accurately; however, significant discrepancies showed us that there was a difference between the mentors and students ratings.

Unfortunately, this difference occurs on a touchy subject as the factor causing the difference in reports is the students' gender. There is little difference between the ratings given by and for male students, but the mentors ratings of female students in the areas of building, programming, and research are much lower than the reports given by the female students themselves.

Figure 11: Mentor vs. Student Report of Researching Ability

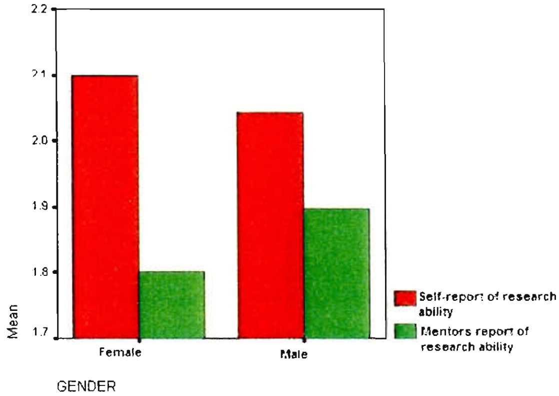


Figure 12: Student vs. Mentor Reported Programming Ability

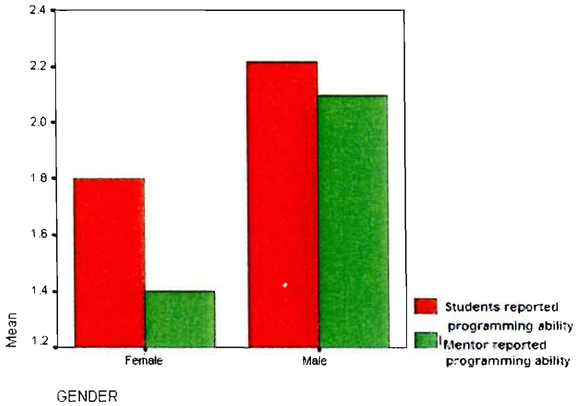
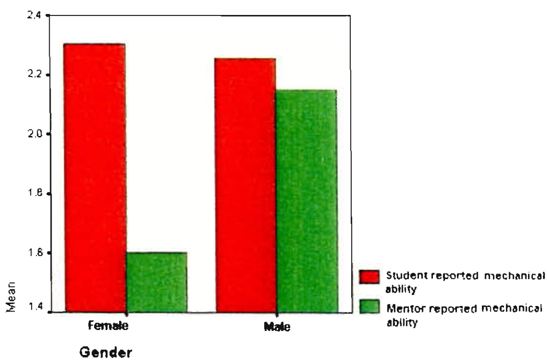


Figure 13: Student vs. Mentor Reported Mechanical Ability



There is no definite answer as to why this difference occurs; however, a few theories have been generated. These theories cover subconscious gender bias, differences in the self-rating between male and female students, and simple statistical misfortune.

The subconscious gender bias theory is easy to understand. We feel that it is possible that both male and female mentors *expect* the male students to do better, because that is the traditional response to females and males in scientific fields. We do not suppose that the mentors actively rate males higher, but the gender bias may affect the ratings given.

Another possible explanation is a difference in the view of male and female students. If the male students are more aware of the range of possibilities they may report ratings which coincide more closely with the mentors' results. In this situation the female students may be inadvertently misrepresenting themselves as having higher ability than they should. Based on the actual data, we do not feel this to be the case as many of the female students rate themselves quite low. Overall though, there are far fewer female students, so a relatively small number of outliers could throw off the average.

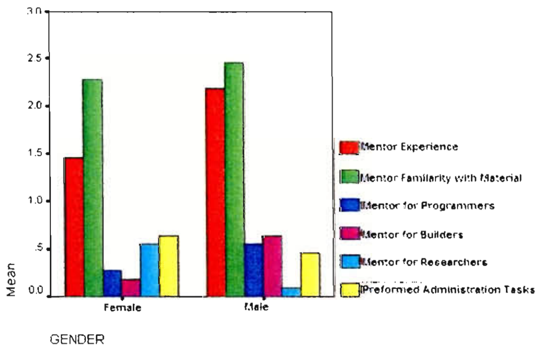
The last possibility we have considered was that of statistical mishap. Due to the low number of female returns, it is possible that a few data points could damage the results significantly. This is unlikely, as stated above, due to the variety of female student returns, as well as the presence of a significant relationship as determined using the chi-squared test discussed in Chapter 4. This relationship showed that the mentor report was dependant on gender, yet even this statistic may have been affected by certain data points.

Overall, the discrepancy in reported skill is heaviest in the construction and research areas and lesser in programming as the female students rate themselves on average lower in this category. In our experiences as mentors on the Mountview teams, as discussed in Chapter 2 Section 4, we have found that all students show equal aptitude in all areas, so whatever the reason for this difference in opinion, it is important for mentors to be aware of it.

Mentor Differences

In order to complete our analysis of the mentors, we must examine any significant differences in the mentors themselves. Based on the results of our initial tests, it was seen that there were no significant relationships between any of the factors (age, gender, experience, skill, etc.) in mentors. All mentors show an equal aptitude for Lego robotics, and the slight variance in prior experience between men and women has no statistical correlation. Other factors, such as age, had no effect on any of the results, and as such do not matter when selecting mentors.

Figure 14: Male vs. Female Mentors



This chart illustrates the above similarity. Both men and women have an equal chance to be very knowledgeable in the required fields, and the differences in the other categories are statistically insignificant. While more males were involved in the construction and programming, this relationship did not signify a relationship between role of the mentor and gender. The reason for this difference in jobs on the team is simply a choice that each team makes, and as such we do not feel it necessary to analyze the mentors in this area.

Chapter 6

Conclusions

6.1 Optimal Team for Learning Experience

The entire purpose of the First Lego League is the academic enrichment and experience of the students. Therefore, teams should be optimized for the most effective learning experience. The only other possible optimization is for a team to be the most purely effective and most apt to win at competition, but this would lead to a less gratifying experience for at least some of the students. This option was not pursued because it is not only a contradiction to the FIRST philosophy, but does not provide a significant advantage over an experience-based team.

The most important aspect of building a good team is the determination of appropriate ratios, and setting limitations on the number of students working on each task. It is generally thought that the more people there are on any kind of a cooperative team, the better that team will be at achieving its goal. This is not always true, and developing a robot as a team is a prime example. Robot design requires planning which must be carried out consistantly throughout the building process. This attention to detail can be difficult with many people who each want to do things in their own fashion. For this reason having many people on a team can make it more challenging to carry out a plan from concept to realization.

The prime categories of work, those which produce the most direct and measurable results, is the mechanical design and construction of the robot. Once the robot's desired functionality is brainstormed and agreed on, the mechanical team needs to put all the parts together and make it work. This process can take a very long time, and usually involves multiple rebuilds of the entire robot. The biggest constraint to this is how many hands can physically work on the robot at once. Research and experience shows that four students is the optimum number for this. A team of four has diverse ideas, yet is manageable. Three and five would be good numbers for conflict resolution methods, because ideas could be taken to majority votes. Five students would be unmanageable after a short period of time, and three would generally not provide diverse enough input to maximize effectiveness and learning through the construction process. For these reasons four members is picked as the ideal number for students on a mechanical team.

The next area of development is that of programming. In order for the robot to perform any of its desired tasks, it needs to be correctly programmed. In this situation, it is found that two or three programmers are the ideal number to have on a team at any given time. The primary limitation to the number of programmers is the number of programs that the robot can store, which currently is five. Next is the number of available computers for the students to use. The study showed that most teams have access to only one computer, with the occasional team having two. This means that, if you have many students who wish to program, there will either be long wait times between turns or, if they decide to work as a group, the process will slow down considerably. Last but not least of the limiting factors is the number of robots each team builds at any given time, which is almost always one. Due to the nature of Lego League robotics, many programs are "guess and check" as students try to get them to function correctly. So, if you need to constantly fiddle with the numbers in a particular program, it then becomes difficult to work on multiple programs simultaneously.

We have found that, while programmers often prefer to work alone, having a small group, usually two per computer, is often more efficient overall. This allows for one programmer to take breaks or miss sessions without all progress stopping. As a group, they can also bounce ideas off of each other in order to better deal with the problems at hand.

Lastly, there are the researchers on the team. This is a hard area to draw any significant numbers in because there are two conflicting ideals. On the one hand, the more researchers you have working the more raw data they will generate Conversely the more raw data you have, the harder it is to form any conclusions and create a presentation based on that data. Because of these two opposing positions, we cannot draw on our own experiences as we have previously, but must base the ideal number purely on the statistics received during the survey. As seen in the pie-chart of team job breakup, it appears that researchers are a smaller population than programmers on the average team. This implies that, on a normal seven member team, there are three or four builders, two or three programmers, and one or two researchers. Unfortunately, none of the jobs are mutually exclusive, so the chart only shows relative frequency and not the actual breakdown of jobs. Overall, it seems that, as with programming, two or three students is the ideal number of researchers. With only one, there is no communication or sharing, which defeats at least part of the purpose of the project. Of course there are no real limits to this number, especially since all students are expected to know the material when presenting at competition, but most current teams have found that small research crews do the job well.

During the survey there were also the categories of leader and operator, which were unexpected roles on the teams. Common sense indicates that there should never be more than one leader per group (mechanical, research, programming) or else power issues may arise. On the other hand, leaders are completely optional and only add to the complexity of the team's structure.

Also optional are the operators on a team. While some teams prefer to have certain students operate the robot during every match, others like to switch it up and give everyone a chance. Unfortunately, there are no conclusive findings on the best number of operators to have. Even so, we feel that every student who desires to have the opportunity to operate the robot then they should have the chance to do so. FIRST Lego League is not about winning, it about learning.

6.2 Program Structure

This section discusses the overall structure of the team, covering topics such as how many mentors there should be per team to number of hours of work a week. Unfortunately, while this was originally one of the three primary targets for the research, very few returns were returned. Only six overview forms were returned after both sampling dates, and this did not provide sufficient material to perform any statistically significant analysis.

Knowing that the data we received does not represent FLL teams as a whole, we decided to proceed with some basic ideas on what to pursue in creating an efficient team structure. There were very few discrepancies in the data on how often teams met, as well as how many mentors were on a team. Other data that would have ideally been collected concerned sources of funding and meeting locations. Due to the lack of data as described above, these secondary topics were not looked at in detail.

Meeting Times

Most teams ranged between two and four weekly meeting hours. Based on past experience, we feel that this is an appropriate amount of time to ask the students to commit. Meeting times should not be under two hours per session, as this will lead to little work being done. Students in this age range, when grouped with their friends, often are easily distracted and can spend up to the first half hour of a meeting just getting set up and remembering what they are supposed to be doing. The four hour maximum per week is also a good choice, as this is supposed to be a fun activity, and you do not want to ask too much of the students. Also, there is a limit to the attention span of the middle school student. If the meeting is too long, it exceeds that limit and the students will lose interest. Requiring more time than they wish to put in will leave many with negative feelings about the project, which is the opposite of what you want.

We have no data concerning whether attendance was mandatory on most teams, but it is an option if many students are available and interested. This way if some drop out after a time, there will be enough team members remaining to complete the robot. Also, knowing that you need to be there can be an incentive to many students to come and actually learn something.

Mentor Allocation

We found through our surveys that there were very limited numbers of mentors on almost all teams. The numbers were in the range of one to three mentors per team. There were exceptions, and we know of at least one team who had a mentor for each of the students who participated. Based on experience and common-sense, we believe that one mentor per station is acceptable and will maximize the usefulness of each mentor. If fewer mentors are available to a particular team, that is fine. There will be times, however, when some teams need help in more than one area, and having only one mentor can slow down the building process.

On the other hand, having one mentor per student leads to a different learning model than what we have looked at so far. In this situation it is more of an apprenticeship, with the mentors helping in every aspect of construction and leading the students to a finished product. This method can be very efficient at teaching the design process, but might limit the engineering knowledge imparted to the students as they lose out on having to solve some of the problems themselves. It is also important to be careful in this situation not to cross over the line and have the mentors build the robot while the students just watch. FIRST severely discourages this as it is a competition between student teams, no teams of proffessional adults.

In certain programs, there are multiple teams under one "set" of mentors, who help all teams as the needs arise. We have tried this model briefly, and it functions to a degree, but you lose much of the bonding between mentors and students. This is a detriment to the process of mentorship. It also reduces team identity, leading some students to feel they are just part of a larger program instead of a team to themselves. This feeling will decrease the competitive spirit between teams and, in turn, decrease the desire to produce the best product. The background research material included in Chapter 2 of this paper strongly supports this idea. It was shown how important it is for middle school students to feel as though they fit in and belong. Often the opinion and attention of adults other than their parents can be extremely influential.

6.3 Effective Curriculum

In order to be an effective learning tool, mentors must be able to teach the students what they need to know. This can be done in many ways, as briefly described above, although from our research some of these methods work much better than others. The preference the students have for the different instruction methods are heavily dependent on the role each student plays on the team. Therefore in order to maximize teaching efficiency, one must cater to the needs of the group you are dealing with.

In FLL, as mentioned previously, there are three main groups that require instruction, and each needs a different amount of starting material and continued support in order to be most effective. Methods that work wonderfully in one group may only provide limited gains when used in a different field. We also found that the researchers do not like to be helped much at all.

Additionally, it is also important to recognize that, although preferences are an important part of deciding how different groups should be taught, there are certain things that need to be shown, no matter what the preference. This is true particularly in starting material when a group has very little experience. In this case information often must be taught in order to be most effectively understood.

Research also shows that, when teaching, some set of guidelines or a curriculum is very beneficial to both students and instructors. This provides a framework for the teaching process and lets each member know what they are expected to be doing. A curriculum has many different forms, and can be either very detailed or very loose, depending on teaching style and learning preference.

As discussed in Chapter 2 on the Mountview case study, the implementation of a set curriculum and education goals greatly improved the overall knowledge of the majority of students. As long as the students show an interest in actually learning the material to be taught, this method is a good one. According to the data we received however, it was seldom implemented.

Due to the differences in the material and learning preferences for each subject area the recommended curriculum and style options will be discussed for each area individually. Forming conclusions for each topic in this way will lead, we feel, to the best model for effective education. The one factor we favor that most teams do not use is a separate time period before the robotics season in order to introduce the methods and skills necessary for FLL. For each section we will discuss what we feel to be the best topics to teach each group before the season officially starts, and this material will be repeated in the Handbook for help in teaching the students. Based on verbal responses gathered at the competitions, most mentors were interested in these curricula more than any other section, so there is an obvious demand for such teaching tools.

6.3.1 Mechanical

No subject is always the easiest to teach, but for many, mechanical is the most intuitive. It is also the easiest subject in which to create examples. Based on student preferences discussed in Chapter 5, it is apparent that mechanically-minded students prefer to be given examples and dislike being forced to figure things out on their own. This makes sense if you have ever tried to build a Lego robot, because many of the things you need to know are hard to figure out the first time you see them. In this way, examples can be a great teaching tool and, as the mechanical aspect has a physical component, a physical model is very easy to create.

Important aspects the students need to understand when constructing the FLL robots are gear ratios, wiring, sturdiness, and steering. Gear ratios are necessary in order to drive the robot at controllable speeds, as well as to give different devices the power necessary to accomplish the designated tasks. Wiring often confuses new students, as motors will drive in different directions if the polarity of the wires is reversed. Also, many students forget to allow for the necessary room to get the wires from the controller to the motors, and this can sometimes cause real problems. Sturdiness is self evident, as a robot will not perform well if it falls apart half way through a session. Lastly, and probably the most complicated issue to work on, is steering the robot. There are many different models for how to steer, each with its own benefits and drawbacks. Most students, however, will not understand how to create these different systems without being shown once. For more detail on how to teach each of these sections, see the Handbook in appendix A as it contains actual guidelines for the teaching itself, not just the material to be taught.

6.3.2 Programming

In contrast to the students in the mechanical group, those who decide to be primarily programmers show no real difference in preference for instruction methods when compared to those who were not programmers. This means that any system of instruction should be alright, although, most students prefer to be shown solutions to really hard problems. Oftentimes, once the basics of programming are understood, the advanced concepts come naturally and little instruction is needed. This, too, is different from mechanical design where as each new situation arises, new solutions and methods may have to be devised. Thus mentors of the mechanical team will probably play a more active role throughout the process.

The primary topics of interest in programming are, in general, less detailed than those of mechanical. They include the basics of what a program is, as well as an introduction to the programming system the students are required to use. You cannot really go much more in depth than that, as each programming language is very different, and just the concept of what a program is will keep the students busy for about a week or two. After this, they can learn the rest as they go, with the mentor providing support when problems arise.

6.3.3 Research

The last group of students who require instruction are the researchers. This is the only group that shows an increase in preference to be forced to learn it on their own, and we feel that this is a good style of teaching to use once they get started

Topics to teach researchers before they begin are how to conduct internet searches, if they do not already know, and a possible introduction to finding information in a library. Both of these skills should already be in place, but reminding the students that libraries exist can sometimes help. After the research is conducted, a presentation is created and instruction on how to put a good presentation together may be needed at this point. Again, most students will have made presentations before, so this instruction should be brief, if necessary at all.

Using these topics or designating your own can both lead to a well-developed curriculum. For detailed examples and process steps in curriculum creation, see the Handbook, or the Chapter 2 literature review for more information. An established curriculum can significantly help both mentors and students throughout the learning process.

6.4 Recommendations for Future Research

After going through the process as described above, we found that there were things we could have gone further with or done better if given more time. There are many logical continuations of this project, each of which would look into specialized areas of the FLL program and their effects on middle school engineering.

One of the obvious next steps for this project itself is to give out the handbook which was designed, and get some feedback on it. Do the teams like it? Does it contain useful information? Is the content correctly addressing its audience? All of these questions can lead to important revisions in the Handbook for coming years.

The second aspect of handbook evaluation is to see if it actually has an effect on the teams. One of the areas we decided not to look at was actual performance. While we found that this topic would unnecessarily complicate matters without providing useful content, others may find this area easier to quantify. It would be interesting to see if there was a noticeable increase in any areas of team performance using the handbook, and if not, then perhaps it will not play as important a role as we had hoped. Only time (and more research projects) will tell.

Alternative continuations would be to redesign and redistribute new surveys. There were many questions we wanted to know the answer to but neglected to design into the original surveys. We tried to make them as easy as possible in order to encourage teams to fill them out, and this worked to an extent, but more information could only have helped in the search for significant relationships in the data. Open-ended questions are much harder to run statistics on than multiple choice or yes/no questions, but can give much greater insights into the overall feelings of those who participate. We gave participants the opportunity to write two short, open ended responses but, if the time is available to read through and attempt to analyze more general questions, it would provide some more qualitative data to go along with our own previous experiences.

If another group did decide to continue this line of research, it would be interesting if they had no prior knowledge of the program. We came in with certain expectations, many of which were wrong while others were in fact correct, but a clean viewpoint might be able to see some aspects of the relationships between mentors and students more clearly.

There are other options open, and I am sure if you read through our findings and the problems we discuss in deciding on the probable causes for these relationships, you will see many other opportunities to expand upon this study. As a final recommendation, we would like to remind you that scores make the game interesting, but learning is what its about. We have aimed the whole of the handbook and guidelines discussed in this paper at bettering the mentoring process to increase its usefulness, and we ask that you try to continue along these lines if possible.

6.5 Reflections

Throughout this project, many decisions were based on our previous Lego League experience, as well as on common-sense. After completing much of the project, we have though of additional ways to do things that might be helped us. We will go through these reflections in the order that the project was completed.

In the beginning, when we created forms we wanted to keep the forms to one page each. After getting the forms back and beginning to do analysis, we found that we had missed certain items which would have been of great use during the analysis phase of the project. Having better analysis would, in turn, have led to more detailed conclusions, allowing us to create a more accurate and detailed handbook. Unfortunately, these survey holes were not discovered until after the data had been collected. Overall, the forms were visually pleasing and easy to complete, as we wanted, so we achieved our goals on form design. One thing we would do differently now is to simulate a statistacal analysis usng the data we could aquire from the forms. This fake statistical run would help us to locate information that we would need, but do not have a way of getting from the present forms.

During the collection period of the project everything went pretty much according to plan. We attended both competitions as desired, and people did, in fact, fill out the forms when asked. The idea of sending out the surveys so they could be filled out before competition worked well, and we saw much greater returns at Robonautica than at the Quincy state competition. We should have specified further that mentors and parental coaches did in fact have to fill out our waivers, although, after doing more research in educational studies, the entire issue of the waiver came into question. We realized too late that if the teams were school-sponsored, then the coaches had temporary guardianship and could have signed the waivers instead of the parents, but this would only have helped to collect a small number of surveys.

The data basing and analysis went as expected, considering the lack of data in some areas and the emphasis on certain topics in the survey design. The SPSS program used for statistics made many of the tests very easy to perform and created clear visual representations of the data for use in the final paper.

Handbook creation was probably the most fun aspect of the project. Instead of being formal, we were able to take a lighter approach and joke about the joys of working with middle-school children.

The conclusion of the project is that there is not perfect way to teach. Everyone is different so some mentoring techniques will work well for some students but not for others. In The Art of Teaching, Gilbert Highet clearly supported this conclusion by repeatedly stating that teaching is about the feeling and the effort that you put into it not about the formulas for making a perfect teacher. However, though there is not a set formula for teaching there are guidelines that can help make a more effective teacher.

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Chapter 7

Appendix A: Mentor Handbook

7.1 What is a Mentor?

7.1.1 Being a Mentor

As defined by the FIRST Lego League (FLL) program, a mentor is someone who provides technical expertise to a team. While this may be true in many situations, you shouldn't feel as though a technical background is a necessity. During our FLL experiences we have seen all types of people succeed in mentoring, and we have seen the technically minded fail. In order to be a good mentor, we feel you should meet the following requirements.

- Mentoring the FLL program means that you will be dealing with anywhere from three to a horde of middle school children. If you don't think you can handle that age group, then this program isn't for you. It can be hard at times, but knowing that you have helped a child learn something that interests them is worth it. For more information on dealing with these delightful children, see section 3 (dealing with middle schoolers).
- No experience is necessary, but interest and desire to learn is paramount. Many people assume that, because they are not mechanical engineers or professional computer programmers, they have nothing to contribute. The kids you will be working with are

just like any other people, albeit little noisy people. Some know a lot about what they are doing and others are just getting started, so you'll fit right in if you're willing to learn alongside them.

- If you've looked at the FLL website and documentation, they recommend that you have at least 2-3 hours a night, 2-3 times a week, and we have confirmed through our research that the average team meets at most between 3-5 hours per week. This may seem daunting, but there are many successful variations to this program that may work better for you. Even if you don't have time to go to every meeting, just making an occasional appearance and showing interest can be helpful to the team members. Oftentimes, they forget what they are trying to do until someone asks them to explain it.

If you think you still want to give mentoring a try, then this manual can be a helpful resource. After surveying the FLL teams last year and participating on an FLL team the two years prior, we have compiled a sizeable amount of information and recommendations that will help you.

7.1.2 Mentor or Coach?

One other important point to make on the nature of being a mentor is the difference between you and the coach. On many teams this line is fuzzy, with both the coach and the mentor giving instruction to the team, but the coach is the person whose primary responsibility is to handle the administrative details of running the team. Coaches can be excellent mentors, but there should only be one coach per team, and ideally this coach should be an adult instead of a high school student.

7.2 How Lego League Teams Work

There is no one way to make a team work, and no matter whose advise you follow, you will find yourself making changes and adapting to work with your particular team. Instead of telling you what you need to do to succeed, we will instead go over many of the more common structures and any obvious benefits and drawbacks thereof. Do not think you need to use only one of these systems as your basis, but instead look here for ideas.

7.2.1 Division of Labor

One of the most common aspects of team dynamics is the division of labor. There are numerous ways to deal with dividing up the kids. Here are some of the most common types.

Many teams prefer to have set jobs for each student. In this situation it is very easy to tell who is supposed to be doing what, and many of the students gain more experiece in their job under this system. The primary drawback to this system, is that while the kids become specialized, they are not well rounded. Also if your head programmer can't make a meeting and no one else has ever done it, there might be some problems.

Another common system is the "do whatever" system. Instead of giving students specific jobs and expecting them to do them, you instead let the students decide what they will do on a per-meeting basis. The benefits of this are that the students get to do, what they want to do and they have the ability to get experience in everything if they want it. The drawbacks are fairly obvious as well. For example, if no one feels like researching that week, it can be quite a chore for the mentors to convince them otherwise.

One compromise between the above systems is the rotating schedule, in which the students are assigned roles on the team, but the roles cycle through the possible jobs as time progresses. Again, the kids get access to all of the different jobs, which can lead to a well rounded team, but it is sometimes difficult to make the rotating groups capable of performing all of the assigned activities. Many of the kids just won't understand what the prior effort in that job has accomplished, and from time to time they do more harm than good during their turns.

The last simple solution to setting up the team jobs is to have set jobs for the students but rotate them as individuals instead of as a group. This way the people at a particular station always have some experienced members, but others still come and go, increasing the general knowledge base of the team. The drawbacks in this system are all due to the kids' tendancy to want to hang with thier friends. In each of the other systems they stay with the same group or have the option to choose a group each week. However, in the individual rotation system the groups change constantly, which may or may not be a good thing. You may decide you want to try one of the above methods, or come up with your own. Be willing to experiment and try new things if your initial setup doesnt work out. If you try enough things, you'll eventually find something you like.

7.2.2 Gender Separation?

Another of the team dynamics issues is gender breakup. Depending on who shows interest in your team and how your team was formed, you may or may not have a mixed gender group. The single gender groups are much more common, and in some ways are easier to work with. Often, in a mixed gender team the kids will naturally divide up into boy and girl groups. It is up to you to either allow this and work with it to decide upon a job system, or you could require them to work together in mixed-gender groups. There are no real benefits to either approach from a technical point of view, but each system requies different things from the coaches and mentors. The ways of dealing with each group will be talked about in more detail in Section 3.

7.2.3 Mentor Student Relations

Possibly the most important aspect of the team dynamics is that of mentor-student relations. The primary source of mentors are team-members' parents. This makes discipline easier, but it makes it harder for the students and mentors to become "friends". On some teams, high school students are brought in to be the mentors, and this has the opposite effect. The kids are more likely to bond with the high school students, yet they will listen to them less when it comes to discipline.

Depending on your system of team creation, you may have more than one group of students meeting in a location at any given time. We recommend that you have each mentor pick a team and stick with it, instead of "floating" between the teams. This will allow them to learn the kids' habits and personalities better, and will also make the students more apt to listen to them. In this way the mentors are seen as part of the team, rather than just a temporary supervisor.

The most difficult aspect of the mentor-student relationship on a paricular team is discipline. Children are trained to listen to people around the age of their parents. Now, you may not even be asked to deal with discipline on your team; that's up to the coach and the mentors to decide together. Most teams allow the mentors to help out in controlling the students, but others prefer to leave it all to the coach to handle, allowing the mentors to focus on helping the kids.

If you are asked to help out in controlling the kids, then you should discuss exacly what you should do in certain situations with the coach. The following are just guidelines that we have found work well, but every team likes to handle things its own way. It is our opinion that a mentor should never have to handle the discipline beyond asking the child to change his behavior. Yelling is a definate no-no, and if the kids get to a point where talking isn't enough, then it is time to call in the coach, who can then handle the situation as he/she sees fit. There is nothing that kills the good atmosphere faster than a kid getting yelled at, so even coaches should use this as an absolute last resort. Even if they do what you ask them to after a few tries, the kids will usually forget what you said and start to misbehave again within an hour or so. At this point, just ask them again and you get another hour of decent behavior. If there is one trouble-maker in the group, it is also possible to remove him/her from the activity for a time, give the kid a "time out," and that can help to get the group back under control. More information on effective middle schooler management is available in section three.

7.3 Dealing with Middle-schoolers

For many adults dealing with middle school students awakens an intuitive feeling of dread. This part of the handbook is to give you a sample of the slightly terrifying world of adolescent mentality. Don't run away! We know the mere thought of trying to contemplate adolescent mentality scares you but keep in mind that by understanding the kids it is easier to work with them.

Natural curiosity and loads of energy are very common in middle school students. There are always new things that catch their interest. Though this contributes to their abundant energy, it also makes them a pleasure to teach or to watch learn, especially since, as a mentor, you can help direct their curiosity and give them the opportunity to explore. Middle school is the most critical time for sparking interest and motivation in math and science. The key to working with a group of active students is to bring patience and a sense of humor.

Most adults are aware of the deadlines and the consequences of not meeting them on time. During adolescence people are beginning to be more responsiable and understanding deadlines but the key word is begining. Research suggests that, by giving them important intermediate goals, it helps to make students progress and understand there responsibilities because it is more immediate. By making goals for every meeting time or every week it helps students to see the pressing need to work towards the greater goal. It is important to avoid doing the project for them, even if it seems as though they will not meet their goals. We know that some mentors are LEGO fans and want to play just as much as the kids do, but if the kids see the consequences of not completing their goals it will be easier for them to understand the next time.

How do I get the kids to stop moving around and listen? A large part of the adolescents' self-concept is formed from social interactions. This is generally why they work well together when they are excited about a project. At the same time, this is no excuse for not listening. Many times their curiosity overcomes their feelings of obligation to listen. Every mentor has to find their own balance for how much they teach and how much they let students do on their own. Always keep in mind that asking kids to explain what they are taught or what they are doing significantly increases their understanding.

Overall it is important to have fun with the students. Most middle school students are becoming adults and can have some great insight and be a joy to work with. Through our experience, once you get over the initial fear of working with the students you can enjoy what you are doing.

7.4 Selecting a Team Structure

From our research, there are only a limited number of suggestions on how to organize meeting times and regularity. Most teams find it sufficient to meet for 2-4 hours per week. Usually this is done over the course of two meetings, but this is very variable and can be lessened or increased as needed. Just don't make the kids feel like its work and you should be fine. One good way to gauge how often to meet is to see how many kids consistantly show up. If this number seems to drop, then you may want to ask them if the times are too frequent.

On the other hand, if all of the students are interested and you have the time available, then you may wish to increase the weekly meetings. This can allow more work to be done in each session if you lengthen the times, or at least the topics will stay fresh in everyone's mind if you meet more often.

7.5 Teaching a Team

Okay, by now you have a pretty good feel for what you're going to have to do, right?. Well, if you think you still need some pointers on how to teach middle school kids some important science and engineering basics, we have some ways to help you. This section will discuss some very simple and effective ways to teach the general principles behind the subjects, as well as provide some general lessons for use in certain areas such as the programming language.

7.5.1 Mechanical

There are a vast number of mechanical concepts which you can convey to students. This can make teaching the basics of mechanics very easy or very hard, depending on which topics you decide to pursue. We have found through our experiences that the following topics and explanations work well as an introduction and, depending on how in depth you want to go, you can always take things further. Since the explanations of the mechanical concepts is rather long to include in the handbook, we have added a detailed explanations and teaching suggestions of each concept, to our website: www.wpi.edu/ mjohnson/lessonplans.html.

One of the most important mechanincal design principles in FLL is gears. You are going to want to use gears to make your robot move at controllable speeds, and the basics of gear ratios are very easy to understand.

Levers are another important principle to understand. Most of the kids you will be dealing with will intuitively understand levers. They use them every day even if they don't realize it. This should make the task of teaching them about levers easier to explain.

The last important mechanical consideration is how to make the robot move in the first place. Even if you master all of the other mechanisms, it will be hard to get anything done if the robot has no way of moving.

While it is important to understand the devices that make the robot work, it can also be useful to examine the factors that can make a robot not work. Friction is the bane of small lego robots, and can cause all kinds of mischief if not understood. Most of the issues you will encounter with friction will be in trying to make the robot move. Commonly one wheel will be rubbing against the robot, or one of the gears will be clamped too hard against something. This will result in friction or dragging in these parts and slow that section of the robot down. This often leads to the robot drifting towards one side, or one set of wheels, arms, etc. not moving. Before assuming that the motor is broken, you should check to make sure that every piece of the robot can still move freely.

7.5.2 Programming

Programming is often looked upon as the hardest area in which you must instruct your mentees. The concepts can be difficult the first time you see them, and explaining computer language to the inexperienced can feel teaching French to cats. Here are some of the ways we have found to best introduce these important concepts, as well as the definitions of these concepts for those of you who have less experience.

The very first thing to teach about programming a computer, which is often overlooked, is to define what a program actually is. A computer program is a set of instructions the computer follows. Contrary to popular opinion, computers are not "smart." However, they can follow instructions very well. The most effective , and *fun*, way to show this to the kids is to act like a computer or a robot. Tell them that you need to find your way around whatever room you're in to get a certain object. Have them provide you with simple step-by-step instructions, which you proceed to follow as stupidly as you can.

The mentor places a baseball on a table across the room and asks the kids how to get to it. They reply "walk forward," and he proceeds to walk straight forward until he hits a wall or other obstacle. The kids then tell him to turn right, and he turns around in circles...

The most important part of this method is to encourage the kids to improve their details over time. the key word you want to hear is 'until.' "Walk forward until ...." "Turn right until....". At this point you can insert different endings such as a time, like ten seconds, or some other feedback like "until you hit a wall".

Within a half-hour to an hour, the kids should be able to write out a list of instructions for the different tasks you need to do which will accurately get you where you need to go. At this point, congratulate them and tell them they are all official programmers. The rest of it is all in the details of speaking the same language as the robot.

Programming language is simply the words you use to tell the computer what to do. These can be actual English words, pictures, or just numbers, but in the end it's the same as learning any other language. You just need to put the right words in the right order. We wish we could provide an easy how-to on programming, but each language is different and whole books can be written on each one. Your coach will select the software he wants to use and you just need to take the time to learn it.

When selecting software you want to look at two things: ease of use and power. Often as the power inherent in the language increases the ease of use of the language goes down. For example, we have used robolab, which we found much more powerful than the basic mindstorms language; however, it takes a little bit longer to understand. In robolab, you string together instructions such as 'motor A forward' with others such as 'until touch sensor 1 hits something' to write out the instructions. This process is very similar to all FLL programming languages; however, the user interface in robolab is icon-based, which means you need to learn the icons before you can get much done. Learning any software just takes time, so sit down for a few hours before you try to teach anyone and poke around to see where all the different pieces are.

7.5.3 research

research

When teaching middle school students research, it is good to remind students of the importance of research and make it applicable to real life. Most kids have some experience with research, so you do not necessarily have to teach them from the start, but you can still give them some friendly reminders. The first and foremost reminder is that the library exists. Both the library and the Internet hold valuable resources and are the keys to research. Occasionally, we have seen students feel compelled to pull research out of their heads rather from valid sources. You may also remind them that everything that is found on the Internet is not necessarily correct. Overall, mentoring research is straightforward. Just make sure the students stay on task, help them when they need it, and let them do their own thing.

7.6 preparing for competition

When trying to decide what needs to be done before competitions, each team has its own goals and preparation methods. There really isn't any quick checklist you can complete to win, or to score 100 points every match, or whatever you state your goals as. However, we can provide some general guidelines on what to expect, and how to go about making certain decisions.

The most important things to have before going to compete are goals. We make no claims to know the best goals to set in your first year; however, it will help everyone on the team if you define some goals before heading out. This way, instead of just going to "compete," the kids know what they need to do. Whether you want to make one program run perfectly, or to just get 50 points, or to learn how other teams built their robots, it will be easier to accomplish if you know that thats what you are trying to do.

The second most important thing to bring with you is a robot. "Haha," you say, "who would go without a robot?" Well you would be surprised at what shows up. When we say robot, we mean something that can move at least one part of itself and has at least one program to do this movement. We have seen very complicated machines collapse and leave the teams with nothing to do the rest of the day but sit around, and we have also seen simple chassis with wheels and a "go forward" program score very well. Whatever your goal, you might want to bring along a go-forward-bot if you don't have anything else done yet. This will give the kids at least a little excitement and experience.

If you have built a complex robot that seems to work well, congratulations! One common problem we have seen with complex robots is that they tend to get dropped and broken more than the simple, easy to fix robots, for some reason. We recommend bringing at least one kid who knows how to put a robot together in case of the worst possible scenario. Hopefully everything will work out fine, but we both know that if you dont know how to fix it, it will get broken.

Other than that, the only other recommendation on items to bring with you is a smile. Weve seen happy coaches with happy teams, and stressed out coaches with stressed out teams. FLL is about getting the kids to like science, technology, and robotics, so try to make sure they have fun. If things aren't working out, set a new goal that they can hit, or bring a bag of Halloween candy as a prize at the end of the day. Whatever you want to do remember: its all about the kids, not about winning.

Chapter 8

Appendix B: forms

The following sheets are the survey forms as given out at competition.

Team Number: [ ]

This form is also available at www.wpi.edu/~sherman/fllsurvey/

STUDENT

Student Form
(to be filled out by student)

Student Name________________________

1. How old are you? ______________
2. Gender:__________
3. What grade are you in? __________
4. How many years of Lego league have you done? (including this one)________
5. What is your role on the team? ______________________________

Please rate yourself on the following tasks:

	Beginner	Intermediate	Advanced	Did not attempt
Ability to Program				
Mechanical Design and Construction				
Research Project				

6. How helpful is your mentor?
   [ ] couldn't have done it without them
   [ ] helped some
   [ ] just supervised
   [ ] was not helpful
   [ ] did the work for me

7. What type of mentor do you prefer (if you have more than one mentor, then please indicate which attribute is most important)?
   [ ] gives example
   [ ] shows solutions to hard problems
   [ ] forced to learn on own
   [ ] provided any solution when asked

8. Did the mentors help you analyze the strategy?_______________

9. Is there anything else you would like to comment on regarding your interactions with your mentor?

10. Is there anything you would like to express concerning interactions with other students on the team?

S_1.1

MENTOR 1

Team Number: [ ]

Mentor Evaluation
(each mentor complete one)

Mentor Name ___________________________

1. How old are you? __________
2. How many years of experience mentoring do you have? _____
3. How familiar were you with the subject matter before you started?
   [ ] Never seen it before
   [ ] Unfamiliar
   [ ] Familiar
   [ ] Formally Educated
4. Do you have a relationship to any member of the team? _____
   If so what is your relationship? ___________________________
5. What duties do you perform on the team? (Please check all that apply)
   [ ] Programming [ ] Construction [ ] Research [ ] Administration
   [ ] Other (please explain) ______________________________________
   ____
6. Do you work with the students prior to the season kickoff? ______
7. How many hours per week do you work with the students during the season?________
8. How do you mentor (please check all that apply):
   [ ] Teach by giving examples
   [ ] Relate project-specific problems with known solutions
   [ ] Show students solutions to hard problems they encounter
   [ ] Force the students to learn on their own
   [ ] Answer questions only when posed
   [ ] Provide information before it's needed
   [ ] Give goals to work towards

9. Do you analyze the strategy with your students? ___________
10. Is there anything else you wish to contribute regarding your experience as a mentor?
____

M1_1.1

MENTOR 2

Team Number: [ ]

This form is also available at www.wpi.edu/~sherman/fllsurvey/

Student Evaluation

(Please Complete for _Each_ Student)

Student Name________________________________ *(will not be used in data analysis)*

Task	Advanced	Proficient	Poor	Did not attempt
1. Ability to Program				
2. Mechanical Design and Construction				
3. Research Project				

What was this student's overall contribution to the team: (please check one)

[ ]Principal Contributor – *Student develops ideas and works towards executing them*
[ ]Secondary Contributor- *Performs tasks, occasionally creating ideas*
[ ]Observer- *Primarily watches and occasionally when asked performs tasks*

Student Name________________________________ *(will not be used in data analysis)*

Task	Advanced	Proficient	Poor	Did not attempt
1. Ability to Program				
2. Mechanical Design and Construction				
3. Research Project				

What was this student's overall contribution to the team: (check one)

[ ]Principal Contributor – *Student develops ideas and works towards executing them*
[ ]Secondary Contributor- *Performs tasks, occasionally creating ideas*
[ ]Observer- *Primarily watches and occasionally when asked performs tasks*

Student Name________________________________ *(will not be used in data analysis)*

Task	Advanced	Proficient	Poor	Did not attempt
1. Ability to Program				
2. Mechanical Design and Construction				
3. Research Project				

What was this student's overall contribution to the team: (check one)

[ ]Principal Contributor – *Student develops ideas and works towards executing them*
[ ]Secondary Contributor- *Performs tasks, occasionally creating ideas*
[ ]Observer- *Primarily watches and occasionally when asked performs tasks*

M2_1.1

OVERVIEW

Team Number: [ ]

This form is also available at www.wpi.edu/~sherman/fllsurvey/

Program Information
(Please complete only one per program)

1. Total Number of Students ______________

   Total Number of Mentors ______________

   Number of Students you normally work with__________

2. How many weeks prior to kickoff do you start? ______

3. **Where do you meet?**

   [ ] Home [ ]School [ ]Public Building [ ] Private Facility [ ] Other ____________

4. How many computers with programming capabilities do you have at disposal? _____

5. **What is unique about your program?**

   ____

6. **Do you have funding for a source other then the members of the program?** ***(this includes parents and coaches)***____________________

O_1.1

WAIVER WAIVER

Team Number:

Waiver for survey on mentoring methods

The purpose of this survey is to determine the most successful methods of mentoring in middle school engineering education. If you participate in this survey you will be asked to fill out one form as a student, one form as a mentor, and one mentor will be asked to fill out an evaluation of each student. We would also ask one mentor or coach to fill out a program overview to see the general structure of your program. All personal or team data will remain confidential. Any questions or concerns you have can be sent to fllsurvey@wpi.edu

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I have read the above description and understand that my consent implies that I will fill out the appropriate surveys honestly and accurately. None of my personal information will be released, and this survey will not affect any FLL standings or happenings. I also realize that this survey is completely voluntary and that I may end my participation at any time.

If under the age of 18 have the form signed by a parent as well as the participant.

Participant name (printed): ______________________________

Participant signature: ___________________________________ Date: __________

Parent signature: ___________________________________ Date: __________

Please check the box indicating if you want to receive the results when they become available. [ ] yes [ ] no

Team Number:

Waiver for survey on mentoring methods

The purpose of this survey is to determine the most successful methods of mentoring in middle school engineering education. If you participate in this survey you will be asked to fill out one form as a student, one form as a mentor, and one mentor will be asked to fill out an evaluation of each student. We would also ask one mentor or coach to fill out a program overview to see the general structure of your program. All personal or team data will remain confidential. Any questions or concerns you have can be sent to fllsurvey@wpi.edu

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I have read the above description and understand that my consent implies that I will fill out the appropriate surveys honestly and accurately. None of my personal information will be released, and this survey will not affect any FLL standings or happenings. I also realize that this survey is completely voluntary and that I may end my participation at any time.

If under the age of 18 have the form signed by a parent as well as the participant.

Participant name (printed): ______________________________

Participant signature: ___________________________________ Date: __________

Parent signature: ___________________________________ Date: __________

Please check the box indicating if you want to receive the results when they become available. [ ] yes [ ] no

W_1.1

Chapter 9

Appendix C: glossary

Glossary:

- Chi-squared Test -statistical test used to determine if two variables are related
- Cross-tabs Test- method of implementing chi-squared test in SPSS
- Coach- an adult in charge of administration and discipline duties (can be but does not have to be a mentor)
- Curriculum- that material that is being taught and how it is presented
- Egocentrism- When one finds importance in only what pertains to them
- For Inspiration and Recognition of Science Technology (FIRST) - A company that focuses on outreach through robotics competitions for students
- Formative evaluation- an analysis of a program while the teaching is going on
- Lego League- see FIRST Lego League
- FIRST Lego League (FLL) - A middle school extension of the FIRST robotics program
- Mentor- anyone who is involved with teaching the students

- SPSS- statistical data basing program
- Summative Evaluation- an analysis of a program after the teaching is finished
- Taxonomies- method to organize subject matter