ROBOKIDS AFTERSCHOOL PROGRAM

A SUSTAINABLE CURRICULM FOR TEACHING CHILDREN A GREATER AWARENESS AND APPRECIATION OF STEM

An Interactive Qualifying Project
submitted to the faculty of
Worcester Polytechnic Institute
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ABSTRACT

Robokids is a STEM outreach program run by Worcester Polytechnic Institute (WPI) students who act as mentors for children of ages 7 to 14 from Worcester Friendly House. These children come to WPI every week for a two-hour session to work on hands-on STEM-related activities. Although Robokids has existed since 2006 and it has been successful, there were certain aspects that needed improvement such as the program's dependency on a single student leader and the attendance inconsistency of the children, meaning that activities that built upon each other could not be conducted. The overarching goal of this Interactive Qualifying Project (IQP) was defined to be the design of a curriculum for Robokids that was enjoyable, engaging, sustainable, expandable, and shareable.

Preliminary research was conducted with the purpose of collecting expert knowledge in order to design a set of activities per STEM area with their lesson plans. These activities were then implemented and then analyzed through feedback that was collected from all three parties involved: students, mentors, and researchers. Finally, a how-to guide was developed to serve as the finalized curriculum for the Robokids program. This guide was included in a website that was created for the Robokids program in order to make it accessible to anyone interested. All deliverables were also passed on to WPI STEM Education Center for their distribution to other entities interested.

EXECUTIVE SUMMARY

In America, children currently spend less than a quarter of their waking hours a day in school.[1] The majority of children in grades K -12 are not being exposed to learning opportunities within the fields of Science, Technology, Engineering, and Mathematics (STEM). While a high percentage of these children have access to many technological devices such as smart phones, computers, scientific calculators, etc., not many of them have an appreciation of the importance of STEM in the development of such devices. It is evident that there is an urgent need for afterschool programs that can broaden the opportunities that children have to STEM exposure in their daily lives.

This Interactive Qualifying Project (IQP) established as its focus an existing STEM outreach program at WPI known as Robokids, which since 2006, has worked together with Worcester Friendly House serving as an afterschool program that works with children on hands-on STEM-related activities. The researchers of this IQP identified lack of organization as one of the program's main problems, since management and knowledge were not successfully transferred through the different iterations of the club. After analyzing the issues leading to the club's lack of organization, it was determined that designing a sustainable curriculum, especially for the Robokids program with the objective of teaching the children a greater awareness and appreciation of STEM, could serve as a great catalyst to improve the effectiveness of the program. The development of such a curriculum immediately became the overarching goal of this IQP. It is important to note that the purpose of this IQP was not to convince children to become engineers or scientists, but simply to increase their literacy and proficiency within the STEM fields.

[1] Children's Defense. (2003)

This IQP was divided into two main components: Research & Design, and Implementation & Analysis. The Research & Design component was dedicated to the collection of expert knowledge that could serve to guide the development of a Robokids curriculum. This was achieved through the following steps:

1. Teacher Focus Group conducted with the Science department from Forest Grove Middle School.
2. Teacher Interview with a teacher from Grafton Street Elementary School.
3. WPI Undergraduate Population Survey conducted to gather activity ideas.
4. Former President of Robokids Interview regarding the past management and activities of the club.

The knowledge gained was combined with Internet research to design lesson plans for the set of activities gathered.

The focus of the Implementation & Analysis component was the practical application of the conclusions drawn from the Research & Design component. This was achieved through the following steps:

1. Continuous testing of the designed activities, and their critical observation and evaluation in order to judge their success.
2. Creation of surveys to measure the effectiveness of each activity.
3. Evaluation of each activity based on both subjective observations and numerical data collected via surveys from the children, college mentors, and researchers.

The preliminary results from this component were used to guide further analysis to find generalized trends and create a "How-To Design a Lesson Plan for Robokids" guidebook that will allow future Robokids officers to create successful new activities.

From the information gathered as part of the Research & Design component of this IQP, an adequate way to design a preliminary curriculum that could be put into practice to test its effectiveness was determined. This preliminary curriculum consisted of a series of activities to be conducted following specific lesson plans written by the researchers of this IQP based on the recommendations obtained and the extensive Internet research conducted. It was determined that in order to make the activities effective, engaging, and enjoyable for both students and mentors, the lesson plans need to contain the following:

1. Motivation and Objectives
2. Background knowledge for mentors
3. Step-by-step guide on how to conduct the activities
4. Classroom management guide with questions to ask to allow intelligent discussions of the topic being covered with the purpose of having mentors guide the students and let them discover things on their own rather than just lecturing them.

The responses to the weekly surveys given by the children and the combined responses of the researchers and college mentors, which were all collected during the Implementation & Analysis component of this IQP, were compared for three categories: enjoyment, independence, and impact. The responses to the general survey given by the children were analyzed to obtain a general perception of the program at its beginning stage based solely on the children's opinion.

After nearly three terms (B, C and D) of the 2012-2013 academic year of continuous research, design, and testing the researchers of this IQP have produced a set of optimal lesson plans that constitute the official curriculum of the Robokids afterschool program for the year to come.

Researchers recommend the use of each lesson plan together with their instructions in order to obtain the best possible outcomes in terms of enjoyment, independence, and impact for all parties involved. Lesson plans can be found separately in the How-To-Guide (i.e., the complete Robokids Curriculum booklet) at the end of this report. Other sources containing that data are the Robokids website [2] and the STEM Education Center at Worcester Polytechnic Institute.

Researchers also recommend the continuous training of mentors. It was discovered throughout this IQP that proper mentor training improved the outcomes of activities in all three categories: enjoyment, independence, and impact. Mentor training could vary from emailing out the lesson plans of the next activities ahead of time to hosting workshops to explain how to guide the children to completing the activities by continuously asking them thoughtful questions rather that telling them what to do or doing it for them. **A mentor to student ratio of 3:1 is also highly suggested for it allows the mentor to focus on a smaller amount of children, thus facilitating the assignment of relevant roles to all members of the group.**

Hands-on activities with clear goals stated from the beginning are recommended as ideal. Children demonstrated to work better when they knew exactly what they were expected to accomplish from the very beginning as opposed to being allowed to explore on their own without specific tasks.

[2] http://wpi.orgsync.com/org/robokids/home

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CHAPTER 1: INTRODUCTION

Currently in America, children spend less than a quarter of their waking hours a day in school.[3] With many different subjects to study and several extracurricular activities to participate in, the majority of the children in grades K -12 are not exposed to learning opportunities within the fields of Science, Technology, Engineering, and Mathematics (STEM). Living in the modern world, a high percentage of these children have access to many technology devices such as smart phones, computers, scientific calculators, etc. without even having the minimum appreciation for the importance of STEM in the development of such devices. There is an urgent need for the implementation of afterschool programs that can diversify the opportunities that children have to experience STEM in everyday life.

Worcester Polytechnic Institute (WPI) has a long history of working with Worcester's Friendly House. In 2006, a program called Robokids was created with the intent of inspiring children from the Friendly House to pursue STEM. The club has gone through several iterations since its creation, as it was adapted in an attempt to best meet the needs of the children. The children are largely from a disadvantaged background, so providing visibility and familiarity with STEM along with the role model presence of college students can have a hugely beneficial impact in their lives.[4]

In the past, LEGO Mindstorms Robotics kits have been frequently used for multiple Robokids' activities focusing mainly on programming and building. These activities usually required the children to build their skills progressively and in many cases, one activity would be split into two different sessions. While the LEGO activities seemed to be appropriate for the

[3] Children's Defense. (2003)
[4] Rhoads, T. R., Walden, S. E., & Winter, B. A. (2004)

Robokids afterschool program, the sporadic attendance of the children eventually frustrated the ones that could not keep with the flow of new material. Moreover, the program suffered from a lack of organization, as management and knowledge was not successfully transferred through the different iterations of the club. Budget limitations were also an issue for the club, thus preventing the purchase of new educational toys. In general, the program faced unique challenges related to designing an effective curriculum.

Given these challenges, and keeping in mind the objective of teaching the children a greater awareness and appreciation of STEM, the overarching goal of this IQP was to design a sustainable curriculum especially for the Robokids Club with a wide variety of activities that: (1) encompass as many areas of STEM as possible, (2) include both short and long activities, (3) can be done in any order and in any combination so as to easily adapt to the needs of the leader, and (4) are inexpensive to supply. It is important to note that the purpose of this IQP was not to convince children to become engineers or scientists, but simply to increase their literacy and proficiency within the STEM fields. The LEGO Mindstorms kits will still be utilized for some activities, but challenges must be carefully designed so that children can complete them in the allotted time. Feedback from previous years indicated children were often frustrated at being unable to complete any of the Mindstorms challenges posed due to a lack of time. Throughout this IQP, an attempt to determine the optimum time allotments for each activity will be made in order to allow the children have adequate time to complete the assignment if they work diligently and not to become bored and distracted.

This IQP was divided into two main components: Research & Design, and Implementation & Analysis. The Research & Design component was dedicated to the collection of expert knowledge that could serve to guide the development of a curriculum. WPI undergraduate population was surveyed for activity ideas. Teachers from local junior high and primary schools were interviewed for their opinions on teaching, keeping students engaged and involved, and classroom management. The former president of Robokids was interviewed regarding the past management and activities of Robokids. The knowledge gained was combined with Internet research to design lesson plans for the activities gathered.

The focus of the Implementation & Analysis component was the practical application of the conclusions drawn from the Research & Design component. This was achieved through the continuous testing of the designed activities, and their critical observation and evaluation in order to judge their success. Surveys were also created in order to measure the effectiveness of each activity. The evaluation of each activity was based on both subjective observations and numerical data collected via surveys from the children, college mentors, and researchers. The preliminary results from this component were used to guide further analysis to find generalized trends and create a "How-To Design a Lesson Plan for Robokids" guidebook that will allow future Robokids officers to create successful new activities.

Three stages of analysis occurred during the course of this project (i.e., throughout the combined Research & Design and Implementation & Analysis components of this IQP). The first occurred after the collection of expert knowledge. This analysis determined the parameters that informed and guided the Implementation & Analysis component of the project, and created the baseline that all of the Implementation & Analysis was judged against. The second stage of analysis took the form of an iterative analysis. This iterative analysis occurred after each lesson plan was implemented and surveys were collected from students, mentors, and researchers. It served as guidelines for updating and changing the lesson plans to better reflect the actual running of the club. The third and final stage of analysis occurred after all lessons had been implemented and feedback had been collected. This analysis was completed to judge the success of the activities and attempt to determine the causes of the successes.

CHAPTER 2: BACKGROUND

In this Chapter, the following five topics are addressed in order to provide a better understanding of the history leading to this IQP:

I. The status and purpose of Robokids at WPI

II. The mission of Worcester Friendly House and its similarity to the objectives of this project

III. The current status of the STEM outreach among children of ages K through 12

IV. An introduction to working with children

V. The overall objectives of this project

ROBOKIDS AT WPI

Robokids was created in 2006 and initially conceived as a *FIRST* LEGO League team.[5] However, the variable attendance by children made this too difficult to execute successfully, leading to student frustration. In 2009 the program switched to using FLL challenges as learning opportunities without the pressure to compete, and in 2010 the program dropped FLL entirely, although they continued to utilize the LEGO Mindstorms Robotics kits.[6]

In the 2009-2010 academic year, E. M. Kurz and A. Smith used Robokids as a basis for their IQP. They designed a curriculum that taught children mechanical and programming skills leading up to a capstone Robotics project.[7] Currently, no remnants of this curriculum exist and Robokids is run almost entirely on improvised, often hastily planned activities. This is due largely to the fact that Kurz and Smith's curriculum was cumulative, as each lesson was designed to build on the previous one. Sporadic attendance of individual children often led to frustration over gaps in their knowledge. Children also did not demonstrate any particular ability to remember technical lessons learned from week to week. This is believed to be due partially to the fact that 5-6 children would share a LEGO kit between them, which often led to one programmer, one builder, and several onlookers. The onlookers frequently became distracted and opted to play with leftover LEGO pieces rather than work with the robot on the lesson material and developed an increasingly large gap in knowledge.

[5] Friendly House to Honor WPI Faculty, Staff, Students (2006)
[6] Coleman (2012)
[7] Kurz, E. M., & Smith, A. (2010)

Robokids was recognized as an independent organization at WPI in early March 2013 after separating from its sister program Exploradreams several years earlier. It will be one year until the Student Government Association allots them an official budget. Previously all supplies, other than the LEGO Mindstorms kits and the laptops for programming them, were purchased with the officers' personal money. Although they now have the option to apply for Special Funding Requests (SFR) or run fundraising activities, the budget available for supplies is unstable and uncertain.

Robokids differs from typical existing programs by possessing a relatively unique combination of characteristics:

(1) Children attend multiple sessions of the program; however, their individual attendance is very rarely consistent, and cannot be planned around.

(2) There is a mix between children who have participated in Robokids in previous years and those who have not.

(3) The program meets once a week for two hours and there must be a break in the middle for the children to eat dinner.

(4) The team possesses four basic LEGO Mindstorms kits but does not possess any additional building blocks, limiting what can be built.

Together, the attendance pattern and the frequency of meetings make Robokids have characteristic of both one-time workshops and regularly meeting, in-depth extracurricular programs. Activities must be chosen to not bore returning children or be too difficult for new children. This is especially critical if the curriculum is to be passed on from year to year. The repetition of activities can be justified by relating it to the engineering concept of iterative design, however it is imperative that the activities remain engaging to the children or have room for variations to make them new again. Returning children must be frequently reminded to work *with* new children, rather than doing the work for them.

The Robokids afterschool program has been evolving and ever-changing since its creation; however, the level of effectiveness needed to reach out and make a lasting impact in the community was still sub-par. Children still faced problems dealing with STEM. A measure of non-bias was needed to achieve an equal impact on the children regardless of age, background knowledge, previous participation in the program, and STEM interest. All these considerations, along with an interest for teaching a wider appreciation of STEM, are what gave origin to this IQP.

FRIENDLY HOUSE

Friendly House was opened in Worcester, MA, in 1920. According to its website, “Their mission was to promote neighborhood health and welfare for the betterment of Worcester and to further the interests of Worcester’s immigrants”. In modern times, they help inner city families in a broad range of areas, including afterschool programs for children. Friendly House’s own summer camp program provides a “safe environment away from the negative influences of the city streets through creative and recreational programs”. [8] The philosophy of Friendly House After-School Program is to help “[foster] an appreciation of self, others and the world around us by providing a variety of activities that stimulate a child’s physical, social, emotional and intellectual development. Self-motivated learning through discovery, exploration and hands-on involvement, coupled with many opportunities for making choices, allow for children’s individual needs to be met while encouraging respect for others.” [9]

This philosophy nicely mirrors the ideas behind an exposure to STEM in which discovery, exploration, and hands-on involvement are paramount. The difficulties and frustrations that are inherent in tackling an engineering problem which challenges the children intellectually also requires them to develop the emotional maturity to cope with setbacks, and working with partners or in groups and with mentors require the children to develop socially. Respect for others – both group partners and competitors – is always required of the children. In this way, Robokids is an excellent partner to the Friendly House.

[8] About Worcester Friendly House (2010)
[9] After-School/Teen Program Worcester Friendly House (2010)

As all children in the Friendly House come from the Worcester, MA area, it can generally be assumed they have an educational experience centered on the Massachusetts Educational Standards for math, science, and engineering/technology. The standards for children in grades PreK-2 are defined as follows:

> "While learning the safe uses of tools and materials that underlie engineering solutions, PreK–2 students are encouraged to manipulate materials that enhance their three-dimensional visualization skills–an essential component of the ability to design. They identify and describe characteristics of natural and human-made materials and their possible uses, and identify uses of basic tools and materials (e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, spools). In addition, PreK–2 students learn to identify tools and simple machines used for specific purposes (e.g., ramp, wheel, pulley, lever). They also learn to describe how human beings use parts of the body as tools."

Students in grades 3-5:

> "Learn how appropriate materials, tools, and machines extend our ability to solve problems and invent. They identify materials used to accomplish a design task based on the materials' specific properties, and explain which materials and tools are appropriate to construct a given prototype. They achieve a higher level of engineering design skill by recognizing a need or problem, learning different ways that the problem can be represented, and working with a variety of materials and tools to create a product or system to address the problem."[10]

[10] Massachusetts Department of Education. (October 2006)

These standards should be taken into account by Robokids to create a learning environment that compliments their schooling experience.

Children who come from the Friendly House to WPI for Robokids are typically coming from a disadvantaged background, have wildly varying degrees of enthusiasm for STEM, and cover a wide range of ages, typically 7-15. As many of the children are not yet even in middle-school most of them do not have a proper grasp on career aspirations. Given these factors the researchers decided to approach the development of an activity curriculum from the standpoint of teaching an appreciation of STEM in their lives and society in general, rather than trying to convert them to the STEM pipeline towards a technical career. Americans live in an increasingly complex society where it is almost impossible to escape the implications and effects of technology. From politics to education to leisure activities, the effect of STEM is felt everywhere. Indeed, one of the potential causes of the STEM crisis is a lack of appreciation and understanding by the general public, particularly educators, administrators, and politicians.[11] By teaching the children a wider appreciation, they will be more prepared for their place in society regardless of what path they choose to pursue.

[11] Wicklein (2004)

STATE OF K-12 STEM OUTREACH

In the last decade, a widespread community has sprung up to promote STEM education. Their actions are widely in response to America's falling rankings internationally in math and science, and the declining numbers of college graduates in STEM disciplines.[12] Robotics is often a favorite tool of these activists as the robots easily apply themselves to multiple STEM fields. Indeed, many experts encourage teaching in multiple STEM fields at once in an integrative approach as it improves children's learning.[13, 14, 15]

These outreach programs typically take one of four forms: integrated classroom instruction, extracurricular clubs, competitive teams, or workshop(s). In terms of meeting frequency and length, Robokids is most similar to an extracurricular club or a series of workshops. However, as mentioned previously, the high level of variability in the attendance of the children makes it difficult to successfully implement a cumulative curriculum that builds skills on top of skills.

The increase in STEM outreach and Do-It-Yourself projects in the last decade has provided a large resource pool of STEM-based activities. In addition to traditional mediums like books, these resources are often posted online for easy access. To fit with our goal of teaching a wider appreciation of all STEM, we are looking for activities in the fields of design, mechanics, electronics, programming, math, and science. Websites like PBS ZOOM, University of Colorado's Little Shop of Physics, NASA's Robotics Curriculum Clearinghouse, University of Oklahoma's Sooner Elementary & Science, Tufts University's Center for Engineering Education

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[12] National Math and Science Initiative. (2012)
[13] Becker, K., & Park, K. (2011)
[14] DeMeis, R. (Feb 2002)
[15] Mitnik, R., Recabarren, M., Nussbaum, M., & Soto, A. (September 2009)

and Outreach, University of St Thomas' squishy circuits, and many others provide activities in almost all these areas.[16,17,18,19,20] Rather than trying to reinvent the wheel by creating a series of activities from scratch, the researchers of this IQP will draw on the numerous resources already available to them and adapt those to meet the needs of the children.

In addition to focusing experience and hands-on activities, many STEM outreach programs focus on technical literacy. "Curriculums are meaningless unless you can evaluate them and the students' learning. The goal is for ALL students to become technically literate, meaning that they have knowledge of technology, are able to use technology, and can critically assess technology. An understanding of technology includes both practical knowledge and seeing the social impacts, pros/cons, etc. of such technology."[21] In the informal atmosphere of Robokids, it is expected this will most likely be accomplished by incorporating references to the effects of technology while working in the classroom, but will best be addressed after doing some initial research and evaluation of the children and activities. As this involves more than a basic activities curriculum, the matter will have to be addressed with the college mentors.

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[16] WGBH. (2010)
[17] Little Shop of Physics (2011)
[18] Dollar, A. M. (June 2006)
[19] Rhoads, T. R., Walden, S. E., & Winter, B. A. (2004)
[20] Thomas, A. M.
[21] Engstrom, D. E. (Dec. 2004)

WORKING WITH CHILDREN

Historically, Robokids college mentors usually take one of several approaches: (1) they remain extremely hands-off and just watch the children to make sure they are not doing anything dangerous, (2) they answer questions the children have and demonstrate how to do certain tasks, sometimes doing the work for the children, or (3) they engage with the children by asking questions to them, prompting them to explain what they are doing and why and to think through the activity without necessarily being given answers. While approaches (1) and (2) are not problematic, they are not exactly what the Robokids program needs to incite the children to learn through discoveries on their own. With this purpose in mind, approach (3) would be the ideal choice to be adopted by all college mentors. It is important to keep in mind that college mentors are simply volunteers for the program and in many cases tend to lack proper training on how to work with children or on how to effectively teach them.

A good solution to these aforementioned issues could be to provide a form of training for the college mentors beyond the purely technical knowledge required – a technique that has been successfully implemented by other existing outreach programs. When these outreach centers have trained teachers how to use STEM in their classrooms, the teachers have been able to integrate their own knowledge of how to work with children into the resulting lessons. A particular technique that teachers often use is learning objectives. Prior to teaching the lesson the teacher determines what the children should know or be able to do at the end of the lesson that they could not do before. The objectives are neither abstract nor include only rote learning, and usually make some nod to how the children will be evaluated in regard to the objective.[22]

[22] Saphier, J., Haley-Speca, M. A., & Gower, R. (2008)

Zones of Proximal Development (ZPD) is a concept created by psychologist Vygotsky that is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers".[23] ZPD has been utilized by several existing STEM programs in order to tailor activities to children and to evaluate the effectiveness of activities.[24, 25] Ideally, if Robokids uses ZPD effectively, children will move from needing mentors' help to complete tasks to being able to accomplish them on their own.

OBJECTIVES OF ROBOKIDS IQP

In summary, the objectives of this IQP were as follows:

Derive a curriculum for Robokids which:

- Matches the philosophy of the Worcester Friendly House.
- Compliments age-appropriate standards for Math, Science, and Engineering/Technology as outlined by the Massachusetts Department of Education.
- Fits within the administrative and financial restrictions of Robokids.
- Can easily be passed on from student leader to student leader with minimal knowledge loss.

[23] Culatta, R. (2011)
[24] Beals, L., & Bers, M
[25] Jimenez Jojoa, E. M. (Feb 2010)

- Will teach all children a wider appreciation of as many aspects of STEM in real life as possible, regardless of their life aspirations.
- Will keep the children engaged regardless of their attendance level, previous participation, or age.
- Will utilize methods such as learning objectives and ZPD to plan activities that meet these criteria.
- Will utilize knowledge gained from experts in the educational and outreach field.

Find generalized trends which:

- Can be used to guide the creation of new activities for Robokids.
- Can be adapted for the creation of new activities for programs other than Robokids.

Give back to the community by:

- Making this IQP's findings accessible to the greater WPI, Worcester, and English-speaking Internet communities.

By meeting these objectives, the goal of designing a curriculum especially for Robokids that can be continued without difficulty over multiple years and teaching the children a greater awareness and appreciation of STEM should be accomplished.

CHAPTER 3: RESEARCH & DESIGN

The Research & Design component was dedicated to the collection of expert knowledge that could serve to guide the development of a Robokids curriculum. The sources to obtain such knowledge were: teachers, former president of Robokids, WPI undergraduate students, and Internet. The knowledge gained was combined to design lesson plans for each activity. It was determined that in order to make the activities effective, engaging, and enjoyable for both students and mentors, the lesson plans need to contain the following:

1. Motivation and Objectives
2. Background knowledge for mentors
3. Step-by-step guide on how to conduct the activities
4. Classroom management guide with questions to ask to allow intelligent discussions of the topic being covered with the purpose of having mentors guide the students and let them discover things on their own rather than just lecturing them.

3.1 METHODOLOGY OF RESEARCH & DESIGN

The Research & Design component of this project took place during B term of the 2012-2013 academic year. The focus of this component was to collect as much background as necessary, complete research, and make a schedule for the Implementation & Analysis component, which was to be conducted during C and D terms of the same academic year. The first step was to create and implement a series of preliminary surveys to acquire basic knowledge to guide the rest of the project. Research was done to determine an initial list of activities and begin transforming the activity descriptions into teachable lesson plans. By the end of B term, the first several feedback surveys were conducted to give some initial impressions and data on how well the procedure worked. Based on this data, the plan for the Implementation & Analysis component could be revised to more accurately reflect the necessary steps.

COLLECTION OF EXPERT KNOWLEDGE

The gathering of sufficient background information necessary to serve as a guide for the development of a curriculum to put into practice was divided into categories as follows:

A. CREATION OF SURVEYS

A series of surveys were planned to gain further background, expert advice, and a broader range of ideas. The preliminary surveys consisted of an interview with the former president of Robokids, Catherine Coleman, an email survey to the undergraduate students at WPI, an interview with a teacher from an elementary school, and a focus group with teachers from a middle school. Each set of questions was carefully worded to avoid biases or leading the answers. After surveys were drafted and revised they were submitted with appropriate forms to the Institutional Review Board (IRB) at WPI for approval.

B. ADMINISTERING UNDERGRADUATE SURVEY

The first survey conducted was for the undergraduate students at WPI. The purpose of this survey was to ask students about fun activities they had done in elementary, middle school, or at home in the areas of engineering, science, math, or technology. The survey was not critical as it was intended only to supplement a collection of activities found by research done on the Internet; it functioned as a sort of expanded brainstorming session. The survey questionnaire was made with the Internet site SurveyMonkey. The questions included in the survey can be seen in Appendix 1.A. An email with the link was then sent to the undergraduate email alias for WPI. The information required for Informed Consent was split between the email and the beginning of the survey.

By discarding repeat answers and vague answers with no helpful information and eliminating activities meant for high-school age students, a short list of answers that were believed pertinent and useful for Robokids was culled. The selected answers can be found in Appendix 1.B. These answers were taken into account when selecting activities to act as the basis for lesson plans.

C. INTERVIEWS AND FOCUS GROUPS

To learn more information about how Robokids had previously been run and how activities had been found, taught, and judged successful, an interview was conducted with the former president of the Robokids club, Catherine Coleman. Catherine was given the questions, included in Appendix 2.A, to read ahead of time so she could think through her answers in order to give a more thorough response. The interview was conducted in person with one researcher asking the questions and recording Catherine's answers with a Flip(TM) video recorder. The interview was then transcribed into a written document which is included in Appendix 2.B.

Finally, in order to properly design, teach, and evaluate activities, the knowledge of experts was required. The best source was judged to be teachers who on a daily basis have to create lesson plans for, teach, and work with students of the same age and approximately the same ability as the children participating in Robokids. To determine the schools to approach, Worcester Friendly House was asked for the schools the children attended. The majority of students attended Grafton Elementary. The Principal was contacted by email and quickly responded enthusiastically. The first middle school contacted, the only one suggested by Friendly House, was East Middle School. The Principal of East felt that her staff was too busy to be able to help. The second middle school, Forest Grove, was chosen by its proximate location to WPI. An in-person meeting with the Principal was arranged to further explain the purpose and aims of the project. The Principal approved and provided contact with the Science Department who agreed to participate.

The focus group was recorded to ensure no information was lost. Equipment was acquired from the Academic Technology Center (ATC) at WPI. They provided a video recorder, a tripod, and a flat table microphone so all the teachers could be recorded clearly. The teachers were asked a series of questions, included in Appendix 3.A, and were allowed to converse with each other and build a conversation regarding the answers. The recording was typed into a transcript, included in Appendix 3.B.

A single teacher from Grafton Elementary School was also interviewed. The same procedure was followed as for the focus group, minus the conversations as there was only a single participant. He was recorded in the same manner with the same equipment. The questions and transcript can be found in Appendix 3.C.

3.2 RESULTS OF RESEARCH & DESIGN

The advice collected from the three interviews ranged from personal connections to classroom management to activity organization and structure. Catherine Coleman, president emeritus of Robokids, provided the most advice in terms of the technical management, structure, and organization of club activities. The teachers focused more on how to interact with and engage the students. Complete transcripts of all three interviews are included in Appendices 2B, 3B and 3C.

Catherine Coleman, who had spent four years with the club, including one as president, gave advice directly from her experience with the club. Her biggest concern was the workload of the club, which historically relied on a single student leader to champion and maintain its existence. Another concern was recruiting college mentors, keeping them involved, and eventually being able to assign tasks and responsibilities to them. In terms of activities she advocated short activities less than an hour with explanations less than 15 minutes, groups as small as possible to the point of individual, and making the activity "legitimate" by making teams and rules and "upping the stakes". She suggested a mentor to student ratio of 1 to 3. In general, her standards were less educational and focused on keeping the kids entertained enough that they were not running, yelling, or texting on their phones.

Mr. Abdelnour, the elementary school teacher from Grafton Street School interviewed, emphasized the need to work on the same level as the students. He encouraged Robokids mentors to build a rapport, feeling free to use humor and be funny, but still remain an authority figure. To manage the classroom he advised avoiding calling out disruptive students in front of their peers and to *always* stay positive. He suggested that talking at a student would not be effective and that they would respond better to a conversation. In fact, he strongly suggested the use of competition as a motivator, so long as the competition was kept fair through differentiated instruction. Differentiated instruction tailors lessons and activities to each student's individual skill level and learning style, and pits students of equal skill level against each other in a competition rather than mismatching the levels. Finally, he recommended developing activities that would develop the students' view of the computer as a learning tool rather than an entertainment portal.

The science department at Forest Grove Middle School focused on holding the students' attention. They repeatedly suggested following a routine every week so the students would grow used to the pattern and respond automatically to commands. Other suggestions including limiting direct teaching to less than 15 minutes at a time, breaking larger activities into smaller tasks, providing multiple tasks to do, but providing instructions only 1 at a time to avoid confusion. They suggested a "no opt-out" policy where students could not dodge questions. They echoed the support of competitions, earning respect, avoiding confrontation, and high positivity. They expanded on the idea of holding conversations with students beyond the classroom management sense, advising that provocative questions that challenge the students' thinking will keep them more engaged and involved. Finally, they encouraged the mentors to model good group work and social skills for the students in order to provide clear expectations.

Internet research introduced more formal educational theories including Papert's Constructionism, Vygotsky's Zones of Proximal Development, and Peer Learning Environment's. One helpful article that discussed all three was a study of Project Inter-Actions workshops where children and their parents learned about and worked on LEGO robots together.[26]

Bers identified four main ideas in Papert's Constructionism, which were considered for use in this research project:

> "…(a) the potential of technological environments to help learners learn by doing, by actively inquiring, and by playing; (b) the importance of objects for supporting the development of concrete ways of thinking and learning about abstract phenomena; (c) the need for powerful ideas that span across different areas of the curriculum; and (d) the premium of self-reflection which engages learners in meta-cognition."

These theories focus on ideas and more abstract concepts of thinking. Alternatively, the Zones of Proximal Development theory focuses on concrete skills and abilities. Increasing a student's independence depends on decreasing their Zone of Proximal Development.[27] This depends on using the concept of scaffolding to challenge the student slightly, while remaining within their capability, and minimizing the assistance given to increase their ability and confidence.[28] Ideally, by reducing students' Zones of Proximal Development Robokids would have a greater impact. By challenging students to stretch their own ability and grow beyond their current state, the students' independence and confidence would increase. This "stretching" could be done by scaffolding. Instructional scaffolding is similar to construction scaffolding – it is put in place to help support while new parts are built and then slowly removed until the new parts can stand on

[26] Beals, L., & Bers, M. (2006). Robotic technologies: When parents put their learning ahead of their child's. *Journal of Interactive Learning Research, 17*(4), 341.
[27] http://www.childrensprogress.com/wp-content/uploads/2012/05/free-white-paper-vygotsky-zone-of-proximal-development-zpd-early-childhood.pdf
[28] Beals, L., & Bers, M. (2006). Robotic technologies: When parents put their learning ahead of their child's. *Journal of Interactive Learning Research, 17*(4), 341.

their own.[29] The removal occurs as students gain more independence, which hopefully would have a lasting impact on the students beyond the club.

The main points of advice found in the collection of expert knowledge were to encourage positive social interactions, to balance students' skills and abilities with each other and the difficulty level of the activities, and to focus on the motivation of both students and mentors.

[29] Beals, L., & Bers, M. (2006). Robotic technologies: When parents put their learning ahead of their child's. *Journal of Interactive Learning Research, 17*(4), 341.

3.3 ANALYSIS OF EXPERT KNOWLEDGE

The information from the teachers interviewed focused on the personal interactions between the mentors and the students. Both the middle school and elementary school groups mentioned the importance of:

- Building a rapport with the students while earning their respect and remaining an authority figure
- Using positivity, patience, and proximity as classroom management techniques rather than yelling or calling students out
- Keeping students engaged by conversing with them and asking questions that challenge their thinking

The majority of their comments focused along these themes, rather than on technical aspects like content, organization, or the structure of the activity. (Although there was strong emphasis on making sure there was a routine or structure of some kind.) This was a critical focus for Robokids. The purposes of Robokids and Worcester Friendly House did not focus on teaching knowledge, but on developing independence, confidence, social skills, awareness, and appreciation. The average mentor who volunteered for Robokids was more likely to be familiar with the technical knowledge referenced by club activities than with the educational and personal knowledge of how to socially interact with the students. The fact that experts noted it as an important skill and an identified weakness in Robokids meant that developing and facilitating proper forms of social interaction would need to be a high priority factor in the design and execution of curriculum activities.

Advice on structure focused on keeping the students involved and busy. Teacher recommendations included following the same routine every meeting. Students know what to expect with a repetitive structure and are more likely to respond to cues that indicate the start of a meeting, dinnertime, clean up time, or other significant transitions. Teachers and Catherine both emphasized the necessity of keeping the students busy by limiting explanations or lecture to less than 15 minutes, keeping activities shorter than an hour or providing a break in the middle, and break larger tasks into a series of instructions provided one at a time. A repetitive routine supported the idea of creating a series of lesson plans for each activity. The lesson plan would make sure each activity adhered to the same format and organization that would provide consistency for the students. Maintaining many of the existing traditions of Robokids would assist in complying with the other suggestions.

The format of Robokids in previous years did lend itself towards keeping the students busy and engaged. Traditionally students would take a break for dinner. In early years, this break took place at the end but Catherine Coleman moved it to the halfway point during her presidency. Maintaining this move complied with advice by all three groups to keep activities short by providing students with a mental break to relax and reduce frustration and stress. The dinner break could also potentially make longer activities possible by making them seem like multiple shorter ones. In previous years, students had asked for longer time to work on robot-based activities. The dinner break would make it possible to attempt a full two-hour period for robot work while still complying with the "less than one hour" recommendation.

Finally, maintaining the small groups with distributed mentors should prevent long, boring lectures and explanations. One of the goals of this IQP was to encourage self-motivated learning through discovery. Long explanations in the form of a lecture are the antithesis of learning by discovery. If the focus of Robokids remained small groups doing hands-on activities, then the only "lecture" needed should be an overview of the task and any rules. While the social aspect of conversations and questioning to build relationships is crucial, the same action puts the focus away from lectures and towards the desired discovery and exploration. Groups even smaller than the traditional 5-6 students per group should be attempted to see if they foster more or less conversation and discovery.

Constructionism is more suited for higher-level research. The ideas of learning by doing and ideas that span a curriculum are inherent in Robokids; the purpose of the project was not to prove the validity or importance of Robokids as these are generally accepted de facto for STEM outreach activities. The connections between concrete and abstract learning and between self-reflection and meta-cognition were more high-level than the concerns of Robokids and the IQP, although a possible avenue for future experimentation and research. It is worth mentioning though, that developing abstract thinking did enter into project when, at the suggestion of the STEM Outreach Center at WPI, the Common Core standards were compared to Robokids activities. This comparison identified that several activities did address the connection between concrete and abstract thinking. However, this was not an intentional guiding factor in the development of the curriculum, and instead a happy coincidence. Overall, Constructivism was not used to analyze the effectiveness of activities.

Zones of Proximal Development and Scaffolding were intriguing concepts that could be considered when designing the curriculum; however, Robokids is not a classroom and the mentors did not have educational training. They could not be expected to fully implement proper instructional scaffolding but they could be guided by the underlying principles. Mentors could provide varying levels of support and guidance to students as necessary. Several of the interviewed teachers discussed differentiated instruction, tailoring instruction to each student's individual skill level, and keeping competition fair by matching equal skill levels against each other.[30] There were two options Robokids could test: make groups by skill level, grouping the advanced students together and putting the others into their own groups, or attempt to make groups of equal average skill by balancing the advanced and less-advanced students across all the groups. Skill-based groups could ease the process for the mentors of providing differentiated instruction. However balanced groups would create fairer competitions; differential instruction could still be possible in the situation, but demand more effort on the mentor's part.

DESIGN OF LESSONS

From the information gathered, an adequate way to design a preliminary Robokids curriculum that could be put into practice to test its effectiveness was determined. This preliminary curriculum consisted of a series of activities to be conducted following specific lesson plans written by the researcher of this IQP based on the recommendations obtained and the extensive Internet research conducted.

A. LESSON PLANS

Possible activities came from four sources:

- The researchers' past experiences with Robokids
- Internet searches

[30] http://www.childrensprogress.com/wp-content/uploads/2012/05/free-white-paper-vygotsky-zone-of-proximal-development-zpd-early-childhood.pdf

- The interview with Catherine Coleman
- The survey to the undergraduate population at WPI

Initially, activities were culled depending on the materials required. Although Robokids was finally recognized by the SGA as an official club during the course of this project, it will be a minimum of one year before it is allotted a budget. Although there was hope for additional sources of outside funding, the club could not continue to rely on the officers to purchase supplies out of their pocket money. These concerns meant all activities had to be inexpensive to supply. An attempt was made to find activities that included building, science, electrical, programming, math, problem solving, and technology.

Subsequently, activities were classified by which STEM area(s) they belonged in. Each activity was then examined for how it could be connected to robotics in an effort to keep a consistent theme of "Robokids". If an activity could not be reasonably connected, it was eliminated from the list. The final list of activities was then separated into high priority activities and lower priority activities to provide a focus should there be conflicts or fewer meetings than possible to implement and test the activities. This list can be found in Appendix 4.A.

Each activity was then written out into a lesson plan. The format of the lesson plan can be seen in the How-To Guide at the end of this report. This format is a modified version of one created by J. Staley and R. Razzaq of Doherty High School – an iteration of an original template provided by Dr. B. Reese, W.S.U. The lesson plan format demanded that each activity be assessed for practicality in terms of supplies, timing, teachability, and that it met the recommendations from Catherine Coleman, the teacher focus group, and the teacher interview. The lesson plans provide a base point to compare effectiveness when the activities are implemented. Several lesson plans can be seen in the How-To Guide at the end of this report. At the end of this project, they could also be passed on to future club leaders to help improve the sustainability of the club.

B. VIDEO LIST

Robokids is typically run with a dinner break halfway through for the children. Occasionally, the mentors would play online videos of robots or cool technology during dinner as an easy way of utilizing every minute of time. To continue this tradition, a list of suitable links was compiled. Criteria for the videos included that they were between 1 to 6 minutes in length, appropriately connected to the STEM ideas pushed by Robokids, and appropriate and understandable by the children. This list of videos can be found in Appendix 4.B.

3.4 CONCLUSIONS OF RESEARCH & DESIGN

From the expert knowledge collected, Robokids was already doing many things well but had several areas for improvement. A small group of children per mentor, a focus on hands-on activities rather than lectures and a dinner break halfway through the two-hour session were all positive characteristics of Robokids. The hands-on nature of engineering activities inherently worked in the club's favor, as it was an instant engagement hook for the kids by keeping them busy and involved.

Possible improvements included making groups smaller and providing more training and encouragement on the social interactions between mentors and students. Thoughtfully planning activities to build upon students' abilities and increase their skills and independence would potentially help the club have a greater and longer-lasting impact on the students. Activity design needed to attempt to highly involve mentors while not making stressful demands on them. There also needed to be a balance between fun and authority. Educational theories and techniques including Zones of Proximal Development, Scaffolding, and Differentiated Learning also provided a guide for optimal lesson design, but could not be used directly due to the mentors' lack of educational training.

CHAPTER 4: IMPLEMENTATION & ANALYSIS

The focus of the Implementation & Analysis component was the practical application of the conclusions drawn from the Research & Design component. This was achieved through the continuous testing of the designed activities, and their critical observation and evaluation in order to judge their success and make the necessary modifications. Surveys were also created in order to measure the effectiveness of each activity. The evaluation of each activity was based on both subjective observations and on numerical data collected via surveys from the children, college mentors, and researchers. The preliminary results from this component were used to guide further analysis to find generalized trends and create a "How-To Design a Lesson Plan for Robokids" guidebook that will allow future officers to create successful new activities.

4.1 METHODOLOGY OF IMPLEMENTATION & FEEDBACK COLLECTION

The Implementation & Analysis component of this project took place during C and D terms of the 2012-2013 academic year. The focus of this component of was to implement activities, collect data, and begin the evaluation of activities and analysis of data, along with the necessary modifications of the lessons. Each Robokids meeting consisted of 1-3 activities conducted. At the end of each activity, the children, college mentors, and researchers were asked to fill out their own unique surveys. The researchers of this IQP also wrote long subjective descriptions of each activity, detailing thoughts, opinions, and circumstances that may become hidden within the answers to the surveys.

COLLECTION OF DATA AND EXECUTION OF LESSONS

At the end of each activity, students and mentors who had turned in their informed consent paperwork were asked to fill out a brief survey about what they thought regarding the activity. They were given the surveys on paper and a writing utensil then allowed about 5-10 minutes to complete the survey. The researchers were on hand to help clear up any confusion over what the questions were asking. Student attendance was also recorded weekly so that an idea of the consistency of student participation could be obtained. The mentor survey can be found in Appendix 7.A, and the attendance record for mentors and students are in Appendix 5.

It was discovered that for some activities, several of the questions in the student feedback survey were not applicable. The questions pertained to if the students were able to finish in time, etc. When the students were following along with an activity rather than working on a task in small groups, they all worked at the same pace. These types of activities were distinguished as "non-producing" to separate them from small-group activities where the children were working to produce a solution. Both the producing and non-producing activity surveys can be found in Appendix 6A and Appendix 6B respectively.

Administration of the feedback surveys and the recording of attendance did not begin until the week of November 26th, 2012. The delay was caused by the process of waiting for approval by the IRB and for the children to return their paperwork. Prior to the week of November 26th the only feedback available was the informal assessment of the researchers.

After the first round of feedback surveys was conducted, it was discovered they provided no insight on several criteria that were judged important to the success of the activity. A third survey, intended for the researchers, was developed to provide a more thorough point of view of the effectiveness of the activity. This survey can also be found in Appendix 8. A. The researchers would have a more in-depth understanding of the different components that go into making a successful activity. Therefore, the researchers' survey reflected more what it had been initially intended as the overall effectiveness criteria. The original proposals for those criteria are included in Appendix 14.

After each Robokids meeting, the data collected from the surveys along with the attendance recordings were entered in Microsoft Excel® worksheets. The collected answers to each question of the surveys can be found in Appendix 6.C (students), Appendix 7.B (mentors), and Appendix 8.B (researchers). An analysis on this collected data was performed to find trends between successful activities and trends shared by non-successful activities, which will be discussed further down in Section 4.2, Results (Implementation & Analysis).

Another more general survey for the students, meant to gauge their overall interest, awareness, and appreciation of STEM was also created. The full "general survey" can be found in Appendix 11.A. Students answered this survey once in C term. This survey was to be administered a second time in D term with hopes that the answers would show an increase over time in the students' appreciation of STEM; however, this could not be accomplished due to scheduling issues. The collected answers for this general survey can be found in Appendix 11.B.

CHANGES IN THE MANAGEMENT OF ROBOKIDS CLUB

During C term, Robokids was in the process of applying for official recognition from the Student Government Association (SGA). As part of this process, the officers of Robokids held several informational meetings and recruited new mentors. The help that the greater mentor to student ratio provided was immediately noticeable; however, many of these mentors were unfamiliar with the activities and software used by Robokids. Subsequently, researchers began emailing the mentors with a summary and basic guide of the planned activities several days before each meeting.

WPI'S STEM CENTER FOR K-12 STUDENT PROGRAMS

The researchers approached the K-12 STEM Outreach Center at WPI to see if the work done as part of this IQP would be of any use to them after it was completed. They were very positive about the idea. Although not necessary, they encouraged the researchers to look through the Common Core standards to see if the lesson plans developed were compatible. The Common Core is a state-created incentive program funded by the Unites States federal government to encourage states to adopt countrywide standards that will better prepare school children for college and careers. [31] Many similarities between skills and behaviors encouraged by the Common Core and practices already used in Robokids were found. A complete summary of these findings is listed below in Table 1.

TABLE 1: List of Compatibilities between Common Core Standards and Robokids Practices

Area	Common Core Standard	Robokids
Math	Make sense of problems in solving them	Going around a maze
	Reason abstractly and quantitatively	Explaining how the robot works abstractly and with specific code blocks (e.g. Peanut Butter Jelly activity, Human Sensors activity)
	Construct viable arguments and critique the reasoning of others	Working in groups
	Look for and make use of structure	Programming: loops, similarity between sensors, right/straight/left motion blocks
	Look for and express regularity in repeated reasoning	
Math Grade 2	Extending understanding of base-ten notation	Numbered Cups activity: e.g., 1's digit only, etc.
	Building fluency with addition and subtraction	
	Using standard units of measure	Ultrasonic Sensors: difference between inches and centimeters
	Describing and analyzing shapes	Programming Shapes
Math Grade 3	Developing understanding of multiplication and division strategies for multiplication and division within 100	Million Dollar Project: calculating taxes Numbered Cups: "working with multiples of 3 only" Programming: $90° = \frac{1}{2}(180°)$
	Developing understanding of fractions	
	Describing and analyzing two-dimensional shapes	Programming Shapes: rectangle, square, triangle, circle, spiral, etc.

[31] http://www.corestandards.org/

Math Grade 4	Developing understanding and fluency with multi-digit multiplication	Million Dollar Project
	Developing understanding of fraction equivalence	Programming: $\frac{1\,rev}{90°} = \frac{2\,rev}{180°}$
	Understanding that geometric figures can be analyzed and classified based on their properties	Programming Shapes Spaghetti and Marshmallow Bridges: structural integrity of shapes.
Math Grade 5	Developing understanding of volume	Duct Tape Boats
Math Grade 6	Using concepts of ratio and rate to solve problems	Power and speed of robot Gears
	Developing understanding of statistical thinking	Numbered Cups with Probability
Comprehension and Collaboration Grade 2	Participate in collaborative conversations with diverse partners	All Robokids sessions are based upon these principles
	Follow agreed-upon rules for discussion (e.g., gaining the floor in respectful ways, listening to others with care, speaking one at a time about the topics and texts under discussion)	
	Build on other's talk in conversations by linking their comments to the remarks of others	
	Recount or describe key ideas or details from a text read aloud or information presented orally or through other media	All Robokids activities are initiates with mentor presenting oral information Students gather information from visual NXT programming guides
	Ask and answer questions about what a speaker says in order to clarify comprehension, gather additional information, or deepen understanding of a topic or issue.	
Comprehension and Collaboration Grade 3, 4,5	Engage effectively in a range of collaborative discussions with diverse partners, building on others' ideas and expressing their own clearly	Robokids offers easy alternatives to written tutorial information. Connect previous lessons on sensors with the programming

	Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion	ones, and so on. Mentors ask, “what does this mean?” “How can we apply last lesson to this?” Easy for teachers to expand on and connect with lessons and use as examples. Information presented: Orally: mentors Visually: programming guides and code Quantitatively: numbers in code and bock settings
	Ask questions, stay on topic, and link their comments to the remarks of other	
	Review the key ideas expressed and draw conclusions	
	Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally	
Literacy Grade 2	Know and use various text features (e.g., captions, bold print, subheadings, glossaries, indexes, electronic menus, icons) to locate key facts or information in a text efficiently	Scratch, NXT software
Literacy Grade 3	Determine the meaning of general academic and domain-specific words and phrases	At Robokids, students learn terms such as: duration, power, sensor, calibration, circuit, resistor, etc.
Literacy Grade 4	Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages)	Scratch NXT Forces on Bridges Electrical Circuits Light Reflection (Easy for teachers to expand upon)
Literacy Grade 5	Explain their own ideas and understanding in light of the discussion	Mentors direct student discussion: “What do you want to do? Why?” Students are directed to work with each other rather than with mentor

	Ask and answer questions about information from a speaker, offering appropriate elaboration and detail	As students become more familiar with code, they should be able to direct more their own learning

4.2 METHODOLOGY OF WEEKLY FEEDBACK ANALYSIS

After all lessons had been implemented and feedback had been collected, a thorough analysis was completed to judge the success of the activities and attempt to determine the causes of the successes. The post-implementation analysis followed the process outlined below:

1. Analyze write-in mentor feedback comments
2. Determine appropriate and relevant grading criteria categories for activities
3. Determine appropriate and relevant method of relating feedback data to grading criteria
4. Combination of responder populations
5. Check balance between each category
6. Create a single grade for each activity
7. Analyze mentor/student ratio and compare to activities' grades
8. Analyze students' general perception of Robokids and STEM
9. Cross-reference with observations to find general trends

This process was designed with the purpose of relating the measurement criteria to the original goals of the project, and then consolidating the data into useful comparisons. A large amount of data was collected for this project that covered many different facets of the project, the club, and the participants. To make the data manageable, appropriate consolidations were made to produce helpful results from which conclusions could be drawn.

Microsoft Excel® was used for storing collected data, executing the equations to combine datasets, and creating the various tables, charts, and graphs necessary to visualize the data. The primary type used was the segmented bar charts to display percentiles of response types for each activity.

The final purpose of this analysis was to judge the success of the activities designed and implemented over the course of the year and to draw general conclusions on how to design successful activities. The general conclusions were necessary to make any sustainable impact of the Robokids program and to extend that impact into the wider community.

DETERMINATION OF CATEGORIES FOR ANALYSIS OF QUANTITATIVE FEEDBACK

To determine if an activity was successful or not, criteria were created to relate the activity feedback to the original goal of the project. This goal was a curriculum that was enjoyable, engaging, sustainable, expandable, and shareable. The purpose of Friendly House's afterschool programs is to promote "self motivated learning through discovery, exploration and hands-on involvement."[32] Robokids takes this a step farther by seeking to "promote an appreciation of STEM in [the children's] everyday lives and to encourage [them] to excel in school."[33] These goals and purposes were reduced to three categories: enjoyment, independence, and impact.

ENJOYMENT: Robokids is a voluntary activity – both the students and the mentors choose to be there. If they do not find the activities enjoyable, neither population will return to the club and will eliminate the idea of sustainability altogether.

INDEPENDENCE: This category recognizes the desired outcome of "self-motivated learning through discovery". Students should be interested in the activity and attempt to solve the problem on their own. Mentors should provide additional information and explanations to encourage learning, but should be able to avoid telling the students what to do or physically

[32] Friendly house website
[33] Robokids

interacting with the students' activity. By encouraging these behaviors, students will be able to discover solutions through their own work, gain more confidence in their ability, and learn skills that they can apply to future activities so that less directive assistance is needed from the mentors with every successive activity.

IMPACT: To encompass the purpose of Robokids, this category relates the students' attitudes to STEM and school outside of the club meetings. The children are not at the age where they are looking at future careers; as such, Robokids does not try to persuade them to pursue STEM careers or even majors. Instead, the club focuses on increasing the children's awareness and appreciation of STEM in their lives.

An activity that is strong in all three categories – enjoyment, independence, impact – successfully meets the goals of this IQP by fulfilling the purposes of Worcester Friendly House and Robokids, strengthening the sustainability of the club, and appealing to other outreach organizations.

DESIGNATING ANSWER LEVELS

Each activity could have varying levels of success in each category. They could fulfill the goal to a high extent, meet the goal to an acceptable extent, or fail to meet the goal entirely. These three levels were given the shorthand names of high, medium, and low, outlined below in Table 2. In order to relate the survey feedback data to the goals, each possible answer to each survey question was rated as indicating a high, medium, or low state.

TABLE 2: Answer Levels and their Meanings

Level Name	Meaning
High	Meets the goal completely
Medium	Reflects the goal to an acceptable extent
Low	Fails to fulfill the goal

Answers that were designated as low indicated some failure to meet all the goals of the activities for the project. In general, low answers would result from negative situations, e.g. students were not even close to finishing within the allotted time, students became frustrated with the activity and possibly gave up, or mentors were unable to effectively assist. A sample of questions and their corresponding "low" answers are listed below in Table 3.

TABLE 3: Sample Low Responses for Selected Survey Questions

Survey	Question	Low Answer
Student	Did you finish the activity in the time given?	No, and not close
Mentor	Were [the children] able to find a solution to the problem?	They were hopelessly lost.
Researcher	Were the kids able to understand the instructions and what was asked of them?	1,2 (high confusion)

Answers marked high were the ideal and medium represented states that were acceptable but could still be improved upon. As determined during the analysis of the expert knowledge, decreasing students' Zones of Proximal Development to have a larger impact on the students was the most desirous condition. To relate collected feedback to this idea, answers that indicated the students had to struggle and ask for help but were still able to reach a solution or were able to find the right line of thinking were marked as high. Answers that indicated students were successful but finished more quickly than expected or found the activity too easy were given the rating of medium. A selection of questions and their corresponding medium answers are shown in Table 4. Selected questions and their corresponding high answers are shown in Table 5.

TABLE 4: Sample Medium Responses for Selected Survey Questions

Survey	Question	Medium Answer
Student	Did you finish the activity in the time given?	Yes, with extra
Mentor	Were [the children] able to find a solution to the problem?	Yes.
Researcher	Were the kids able to understand the instructions and what was asked of them?	3,4 (some clarification needed)

TABLE 5: Sample High Responses for Selected Survey Questions

Survey	Question	High Answer
Student	Did you finish the activity in the time given?	Yes, barely / No, but close
Mentor	Were [the children] able to find a solution to the problem?	Almost, they were on the right track.
Researcher	Were the kids able to understand the instructions and what was asked of them?	5,6,7 (perfectly)

In the case where a question had more than three answers, each answer was still rated in one of the three categories. The sum of responses for all answers per rating for each question was then used for further analysis. Not all questions were included in this analysis. Some were designed more for information gathering and did not reflect upon the three categories determined necessary for the success of the activity, and were therefore excluded from the high/medium/low tallies. In the case of the Cup Stacking with Math and Kit Exploration activities, these were non-producing activities. During non-producing activities students followed the mentors' instructions along with the rest of the group. As such, the non-producing activity survey did not accurately measure the students' perception of their "independence". Therefore for independence for these activities, only the mentors' and researchers' answers were analyzed.

For each respondent population the percentage of answers that were high, medium, low were graphed into a segmented bar chart, with one chart per grading category (enjoyment, independence, impact). There was one bar per activity, and each bar had three segments, one for each level of response (high, medium, low). The three segments always summed to 100% because all the included answers were sorted into one of those three categories.

MATCHING WEEKLY SURVEY RESULTS TO EVALUATION CATEGORIES

Questions from the children's weekly survey, the mentor's weekly survey, and the researcher's weekly survey were divided amongst these three categories. Not all questions in each of the surveys were applicable to this analysis. The complete surveys are included in Appendices 6.A, 6.B, 7.A, and 8.A. The questions included in the round of data analysis are listed below:

Independence:

- <u>Mentors</u>
    - How much did the children struggle with the activity?
    - Were they able to find a solution to the problem?
    - Did you have to provide advice?
    - Did you have to provide hands-on assistance?
- <u>Students</u>
    - How difficult was the activity?
    - Would you change the difficulty of the activity?
    - Did you finish the activity in the time given?
- <u>Researchers</u>
    - Did kids keep trying/not give up and did they find a viable solution?

Enjoyment:

- Mentors
    - Did the majority of the children respond positively to the activity?
- Students
    - Did you enjoy the activity?
- Researchers
    - Were the kids paying attention and not running around, texting, etc.?

Impact:

- Mentors
    - Do you think the activity was effective?
- Students
    - Would you like to learn more about this area?
- Researchers
    - Can the activity (or a full section of it) be completed in less than the allotted time?
    - Were the kids able to understand the instructions and what was asked of them?

The answers for each question were then designated a value of high, medium, or low. Answers rated high represented the ideal case. If the IQP was 100% effective in perfectly designing activities to teach, engage, and inspire students to greater social ability, self-confidence, and interest in STEM, all answers would always be high in all cases. Medium was an acceptable answer and Low answers were those to be avoided or changed.

In rating the answers for the children's survey, included in Table 6 below, it was taken into account that the answers that indicated the children were being challenged, but within their ability level, enthusiastic about the activity, and interested in learning more. Activities that were enjoyable but too easy are preferable to activities that were difficult to the point of frustration/quitting.

TABLE 6: Questions from Children's Weekly Survey included in Analysis, with Answer Levels

Did you enjoy the activity?	
Very Much	High
Just a little	Medium
Not at all	Low
How difficult was the activity?	
Very Hard	Low
Sort of Hard	High
Neither hard or easy	High
Sort of Easy	Medium
Very Easy	Low
Would you change the difficulty?	
Yes, harder	Medium
No, the same	High
Yes, easier	Low
Did you finish in time?	
Yes, with extra	Medium
Yes, barely	High
No, but close	Medium
No, not close	Low
Would you like to learn more about this area?	
Yes, lots	High
Yes, a little	Medium
I don't care	Low
Not really	Low

The mentor questions asked them to rate the success of the students. In this case, desired activities were the ones where the students were hands-on, interested, slightly challenged, and learning new material. Mentors were expected to teach rather than do, which was why the

High/Medium ratings were flipped between assistance and advice. The complete list of questions and levels is below in Table 7. Initially, there were only 2-4 mentors who attended meetings and took the surveys. After recruitment at the end of November 2012 and end of January 2013, numbers increased to 5-6 mentor responses per activity.

TABLE 7: Questions from Mentors' Weekly Survey included in Analysis, with Answer Levels

Did the majority of the children respond positively to the activity?	
Very much	High
Some	Medium
A little	Medium
Not at all	Low
How much did the children struggle with the activity?	
Very much	Low
Some	High
Just a little	High
Not at all	Medium
Were they able to find a solution to the problem?	
Yes	Medium
Almost, they were on the right track	High
They were hopelessly lost	Low
Did you have to provide advice?	
Very much	Low
Just a little	High
Not at all	Medium
Did you have to provide hands-on assistance?	
Very much	Low
Just a little	Medium
Not at all	High
Do you think the activity was effective?	
Yes, completely	High
Sort of, but needs tweaking	Medium
Not at all	Low

The weekly survey for researchers was organized on a weighted numeric scale that was not the same format as the structure for the children and mentors' surveys. For a full copy of the researcher survey, please see Appendix 8.A. The numeric values were grouped together as appropriate and then assigned a high/medium/low value. The researchers' survey included questions regarding organization and sustainability that were not reflected in the other two surveys. For the sake of comparing the three sets of survey results to each other, these questions were not considered in this data analysis. The questions chosen reflected the ideas of enjoyment, impact, and independence in the view of how the activities affected the children participants rather than how the activities affected the organization of the Robokids club. The questions chosen, and the evaluation level of their answer values, are listed below in Table 8.

TABLE 8: Questions from Researchers' Weekly Survey included in Analysis, with Answer Levels

Were the kids paying attention and not running around, texting, etc.?	
4,5 – Focused	High
3	Medium
1,2 – Chaos	Low
Can the activity be completed in the allotted time?	
1,2 – 10+ minutes over	Low
3	Medium
4,5 – Most children finish in time	High
Were the kids able to understand the instructions and what was asked of them?	
1,2 – High confusion	Low
3,4	Medium
5,6,7 – High understanding	High
Did kids keep trying/not give up and did they find a viable solution?	
1,2 – Gave up	Low
3,4	Medium
5,6,7 – Persisted without prompting	High

For each type of survey, the numbers of responses in each level to each analysis criteria were tallied (Appendices 9.A-9.C). For example, the mentor survey for the Linkages activity had four questions relating to independence, which is shown in Table 9 with the tallied responses.

TABLE 9: Tallied Mentor Responses to Independence-related Questions for Linkages Activity

Linkages		
Total # Mentor Responses		2
How much did the children struggle with the activity?		
Low	Very much	1
High	Some	1
High	Just a little	0
Med	Not at all	0
Were they able to find a solution to the problem?		
Med	Yes	1
High	Almost	0
Low	Lost	1
Did you have to provide advice?		
Low	Very much	1
High	Just a little	0
Med	Not at all	1
Did you have to provide hands-on assistance?		
Low	Very much	1
Med	Just a little	0
High	Not at all	1

To calculate the high independence score, the amount of high responses to each independence question was divided by 4, the number of questions, and then summed together. If the question had multiple answers that were high values, the values were added together before being divided. This is shown below in Equation 1.

Equation 1:

$$\text{\# Mentors Linkages Independent High} = ((\text{\# Struggle Some} + \text{\# Struggle a Little}) * 0.25) + ((\text{\# Solution Almost}) * 0.25) + ((\text{\# Advice a Little}) * 0.25) + ((\text{\# Assistance Not at All}) * 0.25)$$

$$\text{\# Mentors Linkages Independent High} = \left((1+0) * 0.25\right) + (0 * 0.25) + (1 * 0.25) + (1 * 0.25) = 0.75$$

The percentage of high independence was calculated using Equation 2: the result of Equation 1 was divided by the total number of mentors who filled out the survey for that activity.

Equation 2:

$$\%\ \text{High} = \frac{(\#\ \text{High})}{(\text{Total}\ \#\ \text{Mentor Linkages Responses})}$$

$$\%\ \text{High} = \frac{(0.75)}{(2)} * 100 = 37.5\%$$

For this example, the final result is that Linkages scored 37.5% high as rated by the mentors. The same process was repeated for Medium, and Low values. Together the three percentages sum to 100% as they encompass all of survey responses.

This analysis was done for mentors (tallies in Appendix 9.A), researchers, (Appendix 9.B) and students (Appendix 9.C). It produced a percentage of high, medium, and low for all surveys for each activity, which are included in Appendices 10.A-10.C.

4.3 METHODOLOGY OF GENERAL SURVEY

The administered general survey included in Appendix 11.A was designed to measure the children's interest, awareness, and appreciation of STEM at the beginning of this research study and at the end with the hopes that the answers to the second round showed an increase in their appreciation of STEM. Due to time restrictions, this comparison could not be performed since a second set of data for this survey was not collected. The first (and only) set of answers was analyzed to determine the children's general opinion of the Robokids program and the ability of the Robokids program to match the kids' interest levels in STEM-related activities.

MATCHING GENERAL SURVEY RESULTS TO EVALUATION CATEGORIES

In order to obtain a general perception of the Robokids program based on the students' opinion, specific categories that could measure their view of the different aspects of the program were defined. Those categories were:

- Science: Are the students exposed to hands-on activities in this field?
- Technology: Are the students exposed to hands-on activities in this field?
- Engineering: Are the students exposed to hands-on activities in this field?
- Math: Are the students exposed to hands-on activities in this field?
- Enjoyment: Are the students enjoying the Robokids sessions?
- Learning: Are the students learning at the Robokids sessions?
- Variety: Are the students satisfied with the amount of variety in the curriculum?
- Motivation to Attend: Are the students motivated to continue coming to Robokids?

- Compatibility with Schools: Do the covered topics complimenting the materials taught in Worcester Public Schools?

Questions from the children's general survey were selected to reflect their opinion regarding each category. Categories that included more than one question were averaged. The answers to each category were designated a value of high, medium, or low in the same manner as the weekly surveys. The complete list of questions and levels per category is below in Table 10.

TABLE 10: Questions from Children's General Survey included in Robokids General Analysis, with Answer Levels

Science	**Has Robokids taught you about science?**	
	Very much	High
	A little	Medium
	Not at all	Low
Technology	**Has Robokids taught you about computers?**	
	Very much	High
	A little	Medium
	Not at all	Low
	Has Robokids taught you about technology other than computers and robots?	
	Very much	High
	A little	Medium
	Not at all	Low
Engineering	**Has Robokids taught you about robots?**	
	Very much	High
	A little	Medium
	Not at all	Low
Math	**Has Robokids taught you about math?**	
	Very much	High
	A little	Medium
	Not at all	Low
Enjoyment	**Do you like coming to the Robokids sessions?**	
	Very much	High
	A little	Medium
	Not at all	Low
Learning	**Are you learning at the Robokids sessions?**	
	A lot	High
	A little	Medium
	Not at all	Low
	[N/A] , [?] or [unanswered]	Low

Variety	**Do you like the variety of activities you do at the Robokids sessions?**	
	Yes, different and interesting	High
	A little, not very interesting	Medium
	Not, really, repetitive	Low
	Not at all, boring	Low
Motivation to Attend	**Will you keep coming to Robokids?**	
	Very much	High
	Just a little	Medium
	Not at all	Low
	[N/A] , [?] or [unanswered]	Low
Compatibility with School	**Have you ever learned the same thing at Robokids and at school?**	
	Very much	High
	Just a little	Medium
	Not at all	Low

The number of responses for each category was tallied. These tallies can be seen in Appendix 12.A. For each category, the numbers of responses in each level were tallied. For example, there were two (2) questions related to the Technology outreach at Robokids. To calculate the high technology score, the number of high responses to each of these two questions were multiplied by ½ and then added together. If a category had a question with multiple answers that were "Low," such as Variety, those were added together. To calculate the percentage of high/med/low for each category, the total weighted sum was divided by the total number of students who filled out the survey. An example calculation is shown below in Equations 3 and 4, which are based on a fragment of the information collected which is displayed in Table 11.

TABLE 11: Tallied Responses to "Technology at Robokids"-related Questions for the General Survey

Technology at Robokids		
Total # Student Responses		9
Has Robokids taught you about computers?		
High	Very much	3
Medium	A little	3

Low	Not at all	3
Has Robokids taught you about technology other than computers and robots?		
High	Very much	5
Medium	A little	1
Low	Not at all	3

Equation 3:

$$\#\ \text{Technology Robokids High} = ((\#\ \text{Computers Very Much} + \#\ \text{Other Very Much}) * 0.5)$$

Equation 4:

$$\%\ \text{High} = \frac{(\#\ \text{High})}{(\text{Total}\ \#\ \text{Student Responses})}$$

This analysis was completed for all categories (tallies in Appendix 12.A). It produced a percentage of high, medium, and low for all categories included from the general survey (Appendix 13.A). These percentages were used to evaluate the Robokids program based on the children's perspective. Since this survey was administered at the very beginning of this research study and middle of the yearly program, the expectations for the Robokids outreach per STEM area were not set above the midpoint. It was also taken into account that children may not be clear on the difference between one STEM area and the other, and thus they could rank one much higher than what it really was while giving a very low score to another one. Therefore, obtaining at least 50% for the combined of medium and high percentages for each STEM area was considered to be sufficient taking into account that there were many more activities to be implemented after the administration of this survey (i.e., on the second week of this research study), and thus these percentages for STEM outreach were only expected to increase progressively. On the other hand, the expectations for the other five categories of evaluation (i.e., Enjoyment, Learning, Variety, Motivation to Attend, and Compatibility with Schools) were set slightly higher since the children's opinion on these other aspects appeared to be more reliable.

There is usually not much confusion to account for when children are asked whether they are enjoying and learning something or not. Similarly, they can easily judge whether they feel satisfied with the variety of activities they engage in and their interest in continuing attending a specific program (i.e., Robokids in this case). Lastly, the question evaluating the compatibility of the Robokids program with schools was very straightforward and the children's response as to whether or not they were learning similar things at Robokids and in school was considered to be sufficiently reliable. Therefore, obtaining at least between 60 and 70% for the combined of medium and high percentages for each one of these five other categories of evaluation was determined to be sufficient for a satisfactory evaluation of this new Robokids curriculum at its initial stage.

A second point of interest regarding this general survey was the students' interest levels in the different STEM areas and the comparison to the STEM exposure at Robokids. In order to do that, selected questions were categorized and designated answer levels in the same manner as previous analysis to capture the students' specific STEM interests. The complete list of questions and levels per category (i.e., per STEM area) is shown below in Table 12.

TABLE 12: Questions from Children's General Survey included in Children's STEM Interests Analysis, with Answer Levels

<table>
<tr><td rowspan="8">Science Interest</td><td colspan="2">Are you interested in science?</td></tr>
<tr><td>Very much</td><td>High</td></tr>
<tr><td>Just a little</td><td>Medium</td></tr>
<tr><td>Not at all</td><td>Low</td></tr>
<tr><td colspan="2">Are you interested in learning about the Earth, outerspace, animals, plants, rocks, or chemicals?</td></tr>
<tr><td>Very much</td><td>High</td></tr>
<tr><td>Just a little</td><td>Medium</td></tr>
<tr><td>Not at all</td><td>Low</td></tr>
<tr><td rowspan="4">Science at Robokids</td><td colspan="2">Has Robokids taught you about science?</td></tr>
<tr><td>Very much</td><td>High</td></tr>
<tr><td>A little</td><td>Medium</td></tr>
<tr><td>Not at all</td><td>Low</td></tr>
<tr><td>Technology</td><td colspan="2">Are you interested in computer science?</td></tr>
</table>

Interest	Very much	High
	Just a little	Medium
	Not at all	Low
	Are you interested in programming?	
	Very much	High
	Just a little	Medium
	Not at all	Low
Technology at Robokids	**Has Robokids taught you about computers?**	
	Very much	High
	A little	Medium
	Not at all	Low
	Has Robokids taught you about technology other than computers and robots?	
	Very much	High
	A little	Medium
	Not at all	Low
Engineering Interest	**Do you build things?**	
	Very much	High
	Just a little	Medium
	Not at all	Low
	Do you take machines, appliances, or electronics apart to see how they work?	
	Very much	High
	Just a little	Medium
	Not at all	Low
	Are you interested in engineering?	
	Very much	High
	Just a little	Medium
	Not at all	Low
	Are you interested in designing building, machines, planes, robots, or electronics?	
	Very much	High
	Just a little	Medium
	Not at all	Low
Engineering at Robokids	**Has Robokids taught you about robots?**	
	Very much	Very much
	A little	A little
	Not at all	Not at all
Math Interest	No record	No record
Math at Robokids	**Has Robokids taught you about math?**	
	Very much	High
	A little	Medium
	Not at all	Low

The number of responses for each category was tallied in the same manner explained above for the Robokids General Perception subsection. These tallies can be seen in Appendix 12.B. Similarly, percentages of high, medium, and low for all categories were obtained. These percentages (Appendix 13.B) were used to determine whether the combined high and medium rankings for the Children's STEM interest levels for each one of the four STEM areas were met (i.e., equaled or surpassed) by the Robokids program or not. If the Children's STEM interest levels were equaled or surpassed, the STEM outreach of the Robokids program was considered adequate. Otherwise, it was considered failed.

4.4 RESULTS AND DISCUSSION OF WEEKLY FEEDBACK

The answers to all surveys were collected and recorded in Excel worksheets. This raw data did not produce any immediate useful results. The results became apparent through the process of analysis. In many cases the interesting and relevant results were the product of multiple forms of analysis accumulated together. These will be explained as pertinent in more detail through the course of the analysis.

During the course of the year, the activities segregated into two types, which affected the data collected. The Mathematical Cup Stacking was classified as a "non-producing" activity. The questions on the "producing activity" survey regarding finishing in time, etc. were non-applicable to non-producing activities. However, these were the questions used to gauge Independence. Therefore, there is no data for student response regarding Independence for the Cup Stacking activity. The producing and non-producing activity surveys can be seen in Appendix 6.A and Appendix 6.B respectively. Although the Racing Robots activity was classified as a "producing activity," the surveys distributed to the students were "non-producing" surveys because researchers did not have enough "producing" surveys to distribute to all the students present at the time. In order to guarantee that all students completed the same type of survey, "non-producing surveys" were distributed. For that reason, there is no data for student response regarding Independence for this activity. Analysis of the correlation between the student responses and the mentor/researcher responses revealed high similarities. For this reason, the gaps were ignored for the purpose of the analysis and did not significantly affect the outcome.

SIMPLIFYING AND COMBINING DATA TO FIND TRENDS AND RELATIONSHIPS

The raw data shown in *Results of Feedback as Sorted by Answer Levels* is very complex and does not produce satisfactory conclusions regarding any cause/effect relationships. Further analysis was used to simply the data model into a more practical form, first by combining the student and adult answers, then by combining the Enjoyment, Independence, and Impact categories. This simplification created a metric that could be used to judge the success of an activity, which would be used in comparison to written data to develop a comprehensive understanding of the factors that influence the success or failure of activities within a curriculum.

COMBINATION OF RESPODENT POPULATIONS

When graphed, the data resulted in each activity having percentages of high, medium, and low responses in each category for each respondent population – a model too fragmented from which to draw useful conclusions. The results from the researcher population were especially variable due to the tiny sample size (between 0 and 2 for any activity). To merge data to create a more simplified model, analysis was done to determine which, if any, respondent population should be weighted more strongly in their judgment of the activities. Based on this analysis, the feedback data from each population for each category was combined together, creating a single set of high, medium, and low percentages in each category. This result facilitated the comparison of the presence of each trait for a given activity.

The researcher data was too variable to determine its correlation to the other populations. Based on the reasonable assumption that the researchers likely had similar opinions to the other college mentors, their peers, the tallies of high/medium/low responses for the researchers were added to those of the mentors, and the number of researchers per activity added to the number of mentors per activity, to create a single “adult” population. The researchers’ results were not weighted more because they were such a small sample size, and weighting their results too heavily would skew the data and make the combination of mentors and researchers pointless.

The new combined adult responses were compared to the student responses to see if the two groups viewed activities differently. By an approximate visual inspection, the two sets of segmented bar charts showed very similar responses to each activity. To better judge the responses’ comparability, the differences were compared using the following equations. Note that the low score is disregarded in Equation 5, here shown with multiplication by zero.

Equation 5:

$$weighted\ score = [(\%high) * 1] + [(\%medium) * 0.5] + [(\%low) * 0]$$

Equation 6:

$$difference = abs[(adult\ weighted\ score) - (student\ weighted\ score)]$$

Equation 6 created a weighted score. This takes into account how similar the answers are to each other. It also favors equations where a difference between scores is in adjoining answer category. For example, if a difference of 10% is moved from high to medium, rather than from high to low. Equation 6 determines the difference between responses for a single activity by taking the absolute value of the adults’ weighted score minus the students’ weighted score. An example of the principle is shown below in Figure 1 and Table 13. Figure 1 shows fictional data where the responses on the left would be considered more similar than the responses on the right because the combined high and medium percentages are more similar.

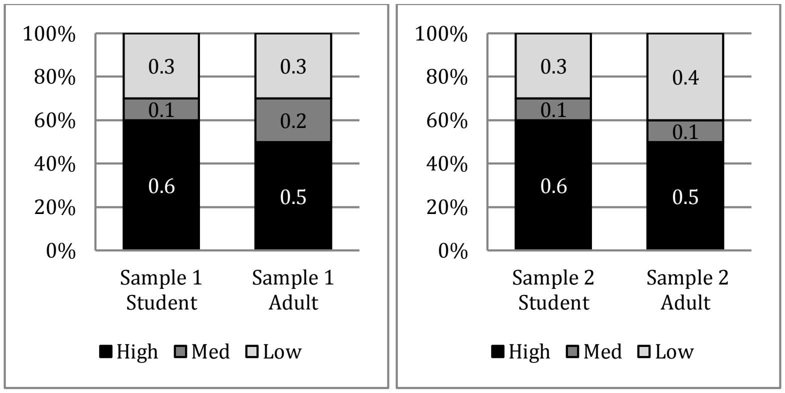

FIGURE 1: Table of Sample Values Demonstration Use of Equation 5 and Equation 6

The mathematical implementation is shown below in Table 13. Greater similarity is shown by a smaller value as the result of Equation 5.

TABLE 13: Table of Sample Values demonstrating Use of Equation # and Equation #

	Student				Adult				Eqn #6
	High	Med	Low	Eqn #5	High	Med	Low	Eqn #5	
Sample 1: more similar	0.6	0.1	0.3	0.65	0.5	0.2	0.3	0.6	0.05
Sample 2: less similar	0.6	0.1	0.3	0.65	0.5	0.1	0.4	0.55	0.1

A difference of 0.3 or greater was a large difference and a difference of less than 0.1 was small for actual values calculated from collected values. The average difference was calculated by averaging the differences from each activity. These average differences justified the method for the combination of the categories into a single set of data for each activity. The combined adult response percentages are included in Appendix 10.D.

COMBINATION OF CATEGORIES

To judge the success of an activity, it was necessary to determine the nature of the relationships between Impact, Enjoyment, and Independence. A ternary plot was created, without weighting any category, to see how balanced each activity was between the three categories. The balance was stable enough that the scores for each category were combined equally to create a single score for each activity.

To combine all three categories together, the percentages within each rating were added together and then divided by three (for the three categories), shown in Equation 7. When this was done to high, medium, and low, the three values often did not sum to 100%.

Equation 7:

$$Combined\ \%\ high = \frac{(enjoyment\ \%\ high) + (independence\ \%\ high) + (impact\ \%\ high)}{3}$$

Equation 8:

$$Normalized\ \%\ high = \frac{(combined\ \%\ high)}{(combined\ \%\ high) + (combined\ \%\ medium) + (combined\ \%\ low)}$$

These normalized values produced a segmented bar graph, which facilitated the most straightforward comparison between activities. This comparison created the grading rubric each activity was subject to, in order to determine the success of the activity.

DETERMINING THE SUCCESS OF AN ACTIVITY

Definitive percentages were demarcated as the bounds of not successful, successful, and highly successful. These limits were chosen in an attempt to accurately portray how activities could meet the standards of the goals chosen at the beginning of the project. These limits led to results that agreed with the subjective opinions found in the mentor write-in feedback and researcher observations. This agreement between the results, the relation of the results to the subjective opinions, and the relation of the interpreted results to the goals of the project meant that the limits were reasonably chosen and the results accurately reflect the rest of the analysis.

Unsuccessful activities were determined from the results separated into the three categories. The goal of this IQP was to create a curriculum that was enjoyable, engaging, sustainable, expandable, and shareable. In order for the curriculum to fulfill all these goals, each activity needed to be strong in three separate areas: enjoyment, independence, and impact. Not succeeding in any one of these three areas meant the activity did not fully contribute to the success of the curriculum. The combined score was not used as it could potentially pull up a failing score. The final demarcation of scores is outline in Table 14 at the bottom of the section.

If the sum of high and medium responses for any individual category was less than 60 %, that activity would be considered failed. High was the ideal state and medium was the acceptable state. If the sum of these two was under 60%, it meant that less than two-thirds of the responders felt that the activity was successful, which is a comprehensible definition of failure. Conversely, any activity that was not failed was successful. Any activity whose combined high and medium percentage was equal to or greater than 60% was considered successful. All the categories and cut-off values are listed in Table 14 below.

Highly successful was set at having an individual high rating of over 50% and a combined high and medium percentage over 80% in all three categories. This value means that at least 4 out of every 5 club participants feel that the activity was strong in all three categories. When dealing with untrained nonprofessionals, whose judgment is subjective and biased, a 20% margin of disagreement is not a significant amount. The resulting "highly successful" activities also felt exceptional to the researchers on an instinctual/subjective level; this agreement validates the value selection. Similarly, the merely "successful" activities felt successful but not exceptional.

TABLE 14: Ratings and Cut-off Values per Category

Rating	Determined By	Condition
Unsuccessful / Failure	3 Categories	High + Medium < 60% In any 1 category
Successful / Acceptable	3 Categories	High + Medium > 60% In all 3 categories
Highly Successful / Exceed Expectations	3 Categories	High + Medium > 80% AND High > 50% In all 3 categories

The frequency of each one of these scores could then be used to judge the success of each activity, the overall curriculum, and a large part of this IQP.

STUDENT/MENTOR RATIO AND RELATION TO ACTIVITY SUCCESS

In the course of the iterative feedback and analysis, it was suggested that the ratio of students to mentors might have had an effect on the success of the activity. The student to mentor ratio was calculated by using collected attendance data. The number of students who attended the activity was divided by the number of mentors present. If the number of mentors varied over the course of a two-hour activity, the average of the number present during 4-5pm and the number present during 5pm-6pm was used as the mentor number. The ratio for each activity was then compared to the segmented bar graph showing the normalized high/medium/low values combined from all three categories and all three respondent populations. The ratio graph was overlaid on the activity segmented bar graph. Visual inspection determined if there was any correlation between activity success and the student to mentor ratio.

CROSS-REFFERENCE JUDGEMENTS WITH OBSERVATIONS

It is crucial for the sustainability of the club that its leaders are able to design new activities in order to expand and vary the curriculum in future years and that these activities are designed in a manner to facilitate the purposes and goals that drive Robokids. The observational and written feedback data were analyzed and cross-referenced against the judgment of successful/not successful for each activity. By finding commonalities between activities with similar results, general recommendations were devised to guide the creation of new activities.

The observations were detailed reports written by the researchers immediately after each activity. The written feedback consisted of write-in comments included at the end of each mentor survey. These comments are understandably subjective and formed a text that could be analyzed by typical literary means. All prior analysis, including the importance and nature of each category as well as the success of each activity, was used as a critical lens. By analyzing the texts through the critical lens, the resulting analysis was able to draw conclusions on what factors contributed to the success of the activity. Some of these factors were intangible from the survey results, and therefore provide a fullness and completeness to the analysis of this project that covers all facets.

4.5 ANALYSIS OF WEEKLY FEEDBACK

The research collected from the sources of expert knowledge formed the guidelines for the development of an initial set of lesson plans. After each lesson plan was implemented, surveys were collected from students, mentors, and researchers. These surveys, plus the loosely subjective opinions by researchers and club leadership, served as guidelines for updating and changing the lesson plans to better reflect the actual running of the club. This updating meant the final form of the lesson plans were more relevant to the needs of the club, while still reflecting the research that went into their creation. This section will discuss the analysis that was done to change the format and how the final form better reflected the goals of the club and of this IQP.

ANALYSIS OF WRITTEN MENTOR FEEDBACK COMMENTS

The mentor surveys included an area for write-in comments regarding how activities could be tweaked to improve them. The comments were analyzed to determine the most common weak points among activities as described previously in the *Methodology* section. The list of categories, and the frequency of comments for each one, can be seen below in Figure 2. The comments were taken from 10 activities where there were between 2 and 7 mentors per activity and comments were optional. Every time an activity was completed, the new mentor comments were added to the collection. These comments inspired updates and the changes to the lesson plan format to make preparation for future activities more thorough and to existing lesson plans to improve activities for future use.

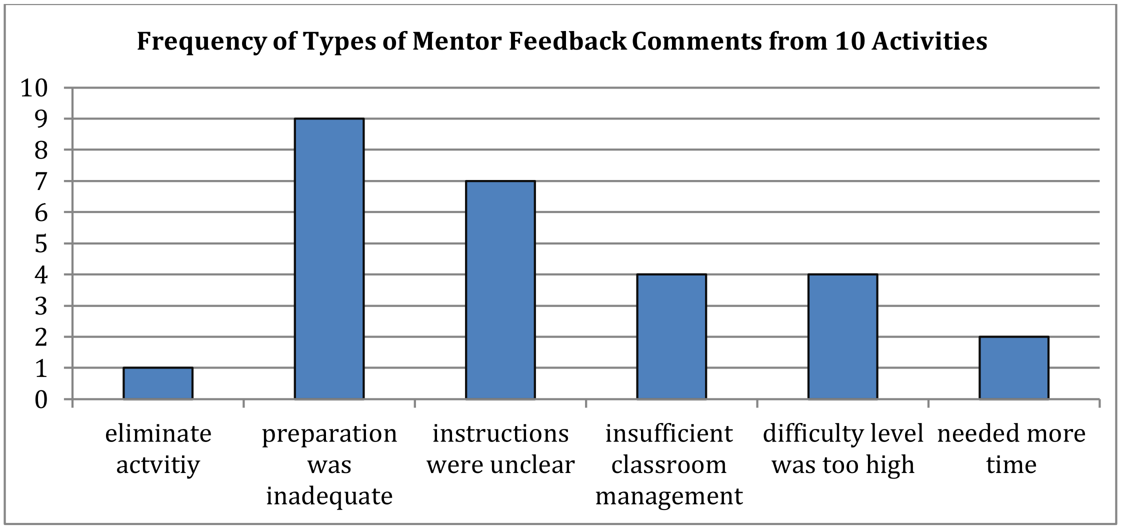

FIGURE 2: Mentor Feedback Frequency per Comment Category

The most frequent comment related to the idea that the preparation by the leaders prior to the activity was insufficient. Examples of these comments included “Make sure the boxes for the maze walls are taped down” for the Three Sensor Maze and “More choices of businesses; greater variety of prices for options within same business” for the Million Dollar Project. These difficulties occurred due to advance planning failing to predict every situation that may occur. The lesson plans were updated to include information and instructions to fix or prevent these situations, which should resolve the difficulties for future attempts. Similarly, unclear instructions and time needs were resolved by making changes in the lesson plans to prevent a repetition of the same difficulties.

The categories of insufficient classroom management and advanced difficulty level were less straightforward to solve. Classroom management difficulties tended to be difficulties keeping the students on task for reasons other than the difficulty level. An attempt at a resolution came in the form of both recruiting new additional mentors and training all of the mentors, new and old. Recruitment allowed for a smaller mentor-to-student ratio so that there was nearly always one dedicated mentor per group of students. Training taught the mentors how to question the students rather than lecture and techniques like using the more advanced students to teach the less experienced students. These techniques, when used correctly by the mentors seemed to help solve some of the classroom management issues and also some of the difficulty concerns.

When the mentors knew techniques to work with the students, they were better able to compensate and adjust for differences in ability level. For example, when one student in a group had not learned division yet, the mentor was able to provide addition and subtraction tasks that still contributed to the group. This improved the classroom management by keeping the student involved, instead of bored and running around, and adjusted the difficulty level down to the ability of the student. Problems with difficulty level and suggested modifications were also added to the pertinent lesson plans so that future leaders can adjust or avoid as they prefer.

Analyzing the mentor comments after each activity provided timely feedback that could immediately be taken into account prior to the next lesson. The changes based on this feedback were then used to update lesson plans to be more helpful to future leaders, improving sustainability and the ability to share the lesson plans. Furthermore they inspired updates to the lesson plan format, which improved the planning and implementation of future activities, increasing the enjoyment and sustainability of the activities. Finally, the feedback was incorporated into general recommendations created at the end of the project, which increased the expandability of the curriculum.

FINAL LESSON PLAN FORMAT

Iterative feedback over the course of the project showed that some changes were necessary to the original lesson plan format. The initial lesson plan format was intended for a standard classroom format: a single teacher lecturing to a large group of students, with occasional questions and short problems. The teaching style was much more directive, focused on communicating information compared to the small group problem-solving format of most Robokids activities. Based on the analysis of feedback provided by Robokids mentors, the lesson plan format was adjusted to be more useful to the club. Table 15 below shows the transition from the original classroom-based lesson plan to the final custom lesson plan format meant for Robokids.

TABLE 15: Lesson Plan Format Transitions

Initial Format	**Temporary Format**	**Final Format**
Length	Length	Length
Notes		Prerequisites
	Integrated Skills/Common Core	Common Core Standards
Motivation		Motivation
Aim/Instructional Objective	Aim/Instructional Objective	Instructional Objective
Material of Instruction	Supplies Needed	Materials Needed
(Notes)		Preparation
	Extensions and variations	Notes for Leader
What mentors need to know		Mentors Need to Know
Development of Lesson	Step-by-step instructions	Explanation for Students
	Questions to ask	Questions for Mentors to Ask
Summary	Summary	Summary

The *Development of Lesson* section reflected the directive nature of the traditional classroom by providing a step-by-step series of instructions, questions, and answers in an ordered format. In contrast, the directive step-by-step sequence was not compatible with the goals of Robokids. The focus on helping students discover the answers for themselves was directly in conflict with the idea of step-by-step lectures and an ordered procedure. The final lesson plan format includes the sections: *What Mentors Need to Know*, *Explanation for the Students*, and *Questions for Mentors to Ask Students*. *What Mentors Need to Know* encompasses background knowledge on the materials and topics that may be referenced during the course of the activity. *Explanation for Students* is the initial explanation of the activity: a brief introduction to the topic, the problem they are trying to solve, and any rules or restrictions on their solution. This was presented at the very beginning of the activity, before the students and mentors were split into groups. When they were in groups, the most relevant section is the *Questions for Mentors to Ask*. These questions are listed in no particular order and mentors may not need to ask all of them during the course of the activity. It is more of a guide, suggestions, and examples to both train mentors and help them when their student group is struggling. This division of information better complements the more informal and exploratory nature of Robokids as compared to a traditional classroom structure.

The hands-on nature of the activities for Robokids made preparation a much larger topic than just the materials needed. The original lesson format implied that acquiring the *Materials of Instruction* was all that was required for preparation. Robokids occasionally necessitated creating mazes, building robot bases, outlining paths, or laser cutting custom gear sets that required more involvement than just acquiring materials. To elucidate this process, the materials and preparation steps were separated into two categories. A future section that could be added to the lesson plan would be how long the preparation took. It cannot be included now as that data was not recorded reliably over the past year. The two sections, *Materials of* Instruction and *Preparation* better reflect all of the pre-activity work that needs to be completed as opposed to a single section.

One goal of the Interactive Qualifying Project was to create a curriculum that could be shared with other groups, including classroom teachers. Classroom teachers in the public education system in the United States of America must contend with the numerous standards that govern what they must teach. Currently states are adopting the Common Core standards, which are national guidelines for state educational standards.[34] Standards limit the outside activities a teacher is able to implement in the pursuit of providing a more well-rounded education. However, robotics, and by extension Robokids' activities, is compatible with many different subject areas. To make this connection and make the lesson plans more attractive to classroom teachers, Common Core standards were identified that were compatible with the tasks done for each activity.

While the final lesson plan format is altered from one meant for classroom usage, it contains enough materials that teachers should be able to adapt it to their own classroom use. Teachers are trained to design lesson plans, and, given the purpose, tasks, and general flow of the activity, it should be fairly straightforward for them to adapt to their own classroom. Therefore, the altered lesson plan format should not damage the ability to share these lesson plans with schoolteachers.

[34] http://www.corestandards.org/

SIMILARITY OF RESPONSES FROM DIFFERENT RESPONDER POPULATIONS

To better judge the comparability between the combined adult and the students' responses, the differences were compared using Equations 5 and 6, previously described in the *Methodology* section. A difference of 0.3 or greater was a large difference and a difference of less than 0.1 was small for actual values calculated from collected values. The average difference was calculated by averaging the differences from each activity. Table 16 below shows the average difference from each category, as well as the overall average difference between all three categories. The average differences were greater than 0.1 and less than 0.3. This indicates that, over the year, the answers correlate relatively well for what was expected.

TABLE 16: Average Difference per Category

Category	Average Difference
Independence	0.236
Impact	0.146
Enjoyment	0.166
Overall	0.183

The level of correlation between adults and students was slightly surprising; large differences had been anticipated. According to the expert knowledge collected through research, the students should have been more fickle in their answers as they were more likely to be influenced by other factors like the weather outside, their lunch at school, or arguments with their peers on the ride to Robokids[35]. It was also accepted that children "do not always know what's best for them"[36] and therefore it was possible that their responses should not heavily

[35] Robokids
[36] Robokids

influence the final conclusions. The opposing viewpoint argued the goals and purpose of the club are dependent on the children's perception of the activities, which inherently includes noise from other sources. If the activities were successful enough in meeting their purposes, the students' perceptions would still be favorable even with the interference. However, since their responses were so close to the mentors' responses, it was not necessary to choose one side of this debate.

COMBINATION OF RESPONSES FROM DIFFERENT RESPONDER POPULATIONS

As there were no significant differences in opinion between students and adults, it was not insightful to compare the two. Instead, these populations were combined by equally averaging both values together. The answer tallies for each rating were summed and divided by the total number of researchers to determine the overall percentages of answers that were high, medium, and low. This combination resulted in a single segmented bar chart for each category, pictured below in Figure 3.

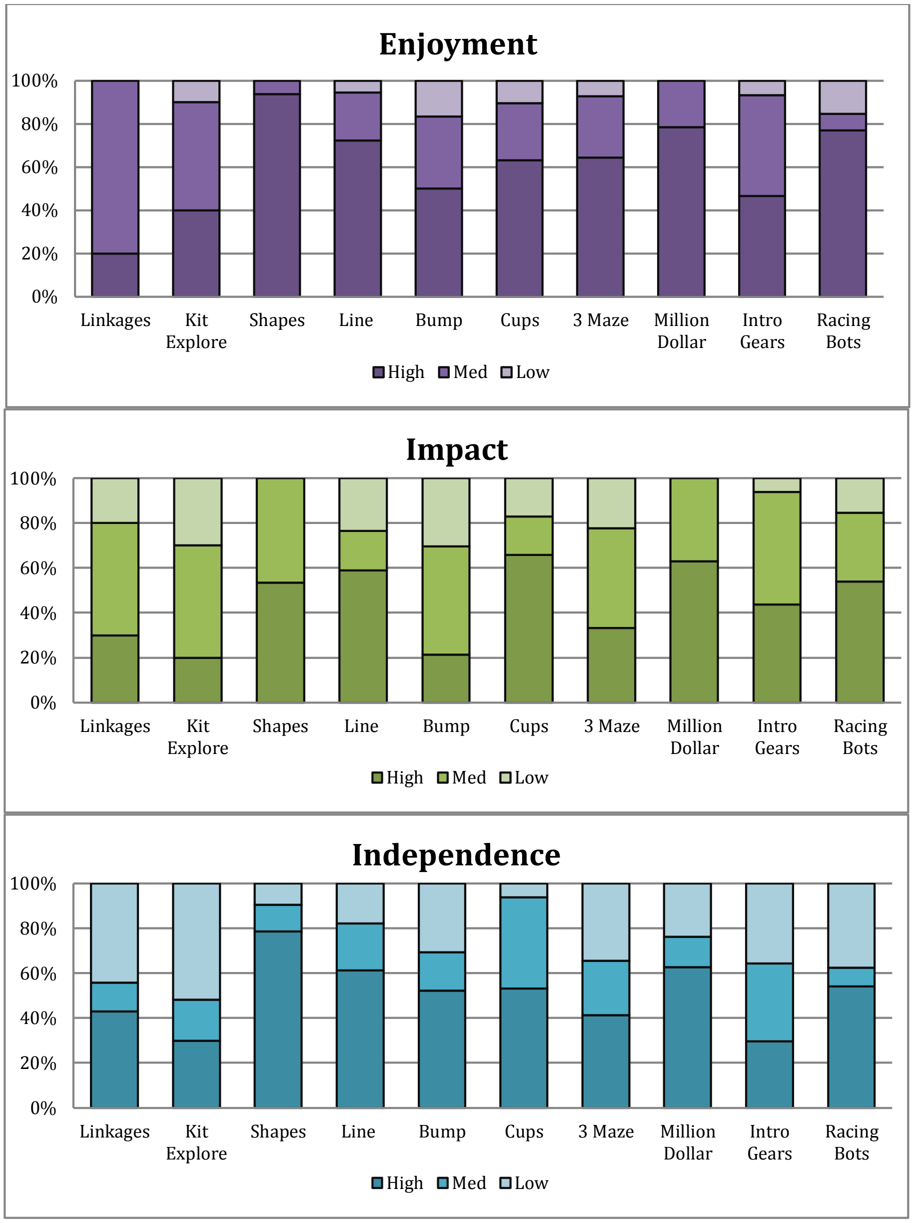

FIGURE 3: Combined Results per Categories for All Activities Conducted

A visual inspection of these graphs begins to show which activities were the most and least successful. The Drawing Shapes programming activity is a clear front-runner in all three categories. The Million Dollar Project and Cup Stacking activities also show strong results. The Linkages and Kit Exploration activities have mixed results, showing stronger in Enjoyment than Impact or Independence. In general, all activities tend to have stronger ratings in Enjoyment and weaker ratings in Impact. These numbers and graphs were considered in the final judgment of success; they also underwent additional analysis to further consolidate the model.

COMBINATION OF CATEGORIES ANALYSIS

The three separate charts did not permit an easy comparison of activities in terms of overall success, rather than in terms of strength in a single category. The most straightforward way to make this judgment was to combine all three categories together into a single ranking for each activity. This combination posed a similar question to the combination of respondents: Should one or more categories be weighted more heavily than the other(s)?

While each of the three categories were equally important to meeting all of the goals of this IQP and reaching the ideal state of the Robokids club, they were not all as crucial at the most basic level. Enjoyment was the easiest category to achieve strong ratings in, and was the most fundamental aspect to the club. If the activities were enjoyable the students and mentors would likely continue to like the club and attend meetings. It was, however, possible for the activities to be enjoyable without the students demonstrating or gaining independence, or being impacted in any meaningful way that would extend outside the club. Similarly activities could have students demonstrate independence without gaining greater independence, being impacted, or even enjoying the activity. Impact was the most dependent on the other two: if students did not enjoy the activity they were unlikely to take anything away from it and increasing independence was an important factor in creating an impact. These characteristics lead to different options for weighting them.

Options for weighting the categories included: (1) weight them all equally, (2) weight enjoyment the most because it is the most fundamental, (3) weight impact the most because it is the highest ideal. When the question of combining respondents was approached, the correlation between the different groups was compared. A similar method was tested here and a ternary plot was created, shown below in Figure 4, without weighting any category, to see how balanced each activity was between the three categories. Racing Bots, Introduction to Gears, and Cup Stacking with Math were slightly offset away from Independence and all of the activities showed a very slight drift towards Enjoyment. These offsets were minimal; all of the activities clustered in the center, showing a balance between the three categories. This balance could indicate that the activity was either equally strong in all three categories or that it was equally weak. However, it was decided that since there were no extreme outliers, all three categories could be averaged together equally.

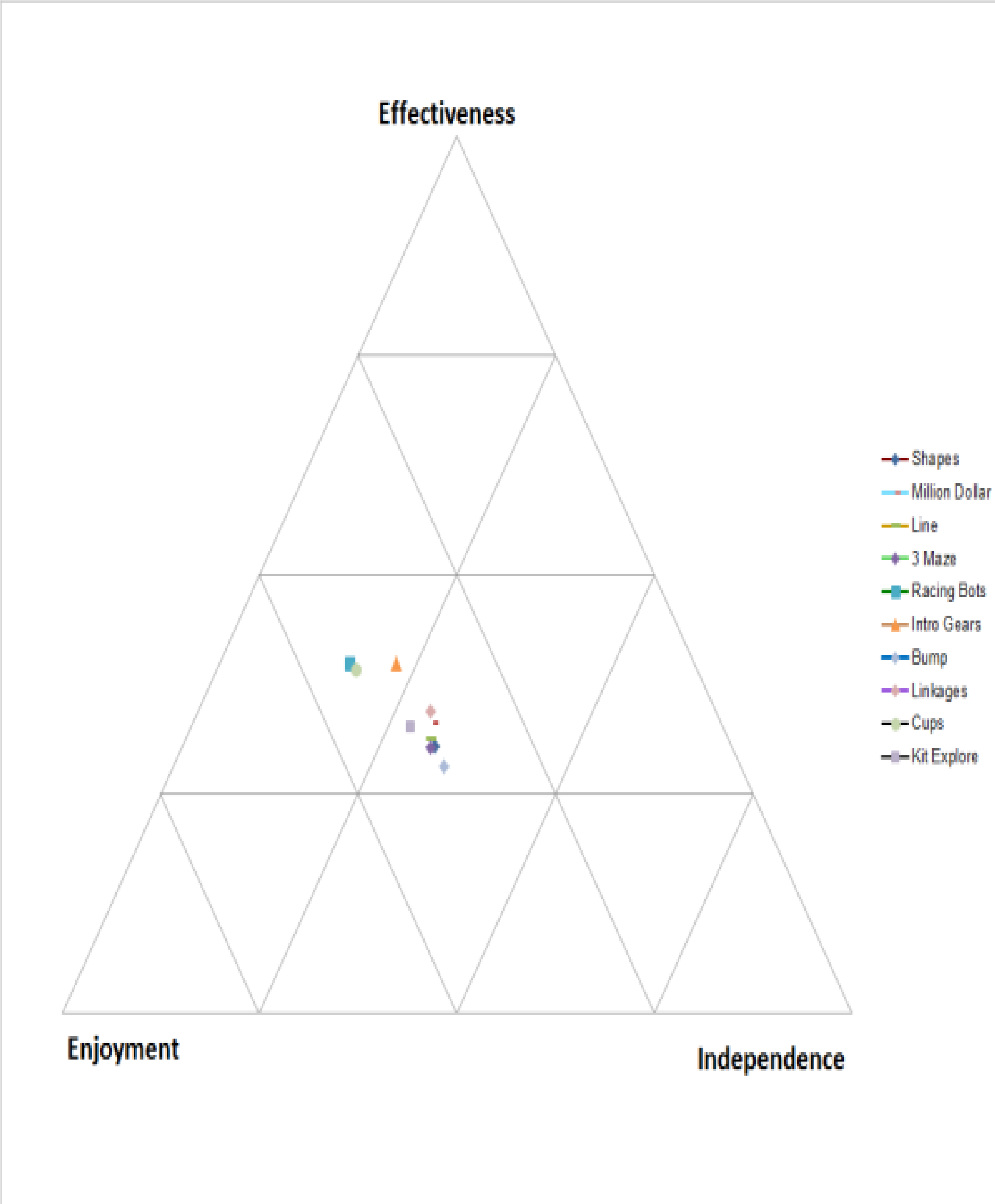

FIGURE 4: Unweighted Ternary Plot of Categories

To combine all three categories together, the percentages within each rating were added together and then divided by three (for the three categories), shown in Equation #. When this was done to high, medium, and low, the three values often did not sum to 100%. Equation # was used to normalize the values by dividing their value by the total percentage value of all three.

Equation 9:

$$Combined\ \%\ high = \frac{(enjoyment\ \%\ high) + (independence\ \%\ high) + (impact\ \%\ high)}{3}$$

Equation 10:

$$Normalized\ \%\ high = \frac{(combined\ \%\ high)}{(combined\ \%\ high) + (combined\ \%\ medium) + (combined\ \%\ low)}$$

These normalized values produced the graph shown below in Figure 5. This creates the most straightforward comparison between activities. The Drawing Shapes activity is the clear front runner, and Million Dollar Project and Line Following continue to have strong showings as well, which correlates with what was visible in the three separate category graphs.

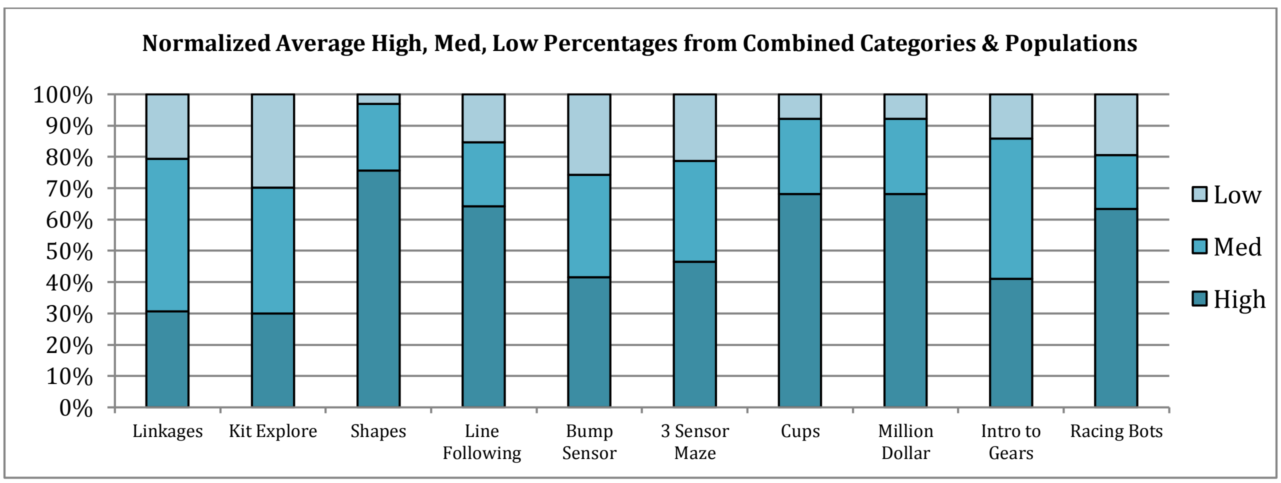

FIGURE 5: Normalized Answer Level Percentages from Combined Categories and Populations

This combined data was used to help compare the results of the success judgments to make sure that the limits made logical sense. Primarily the combined data was useful for representing this project to others not involved with it, as it would be easy to grasp at a quick glance. Based on these results, the ternary chart was updated to reflect the activities score (Figure 6). The larger the circle was, the stronger the activity's score.

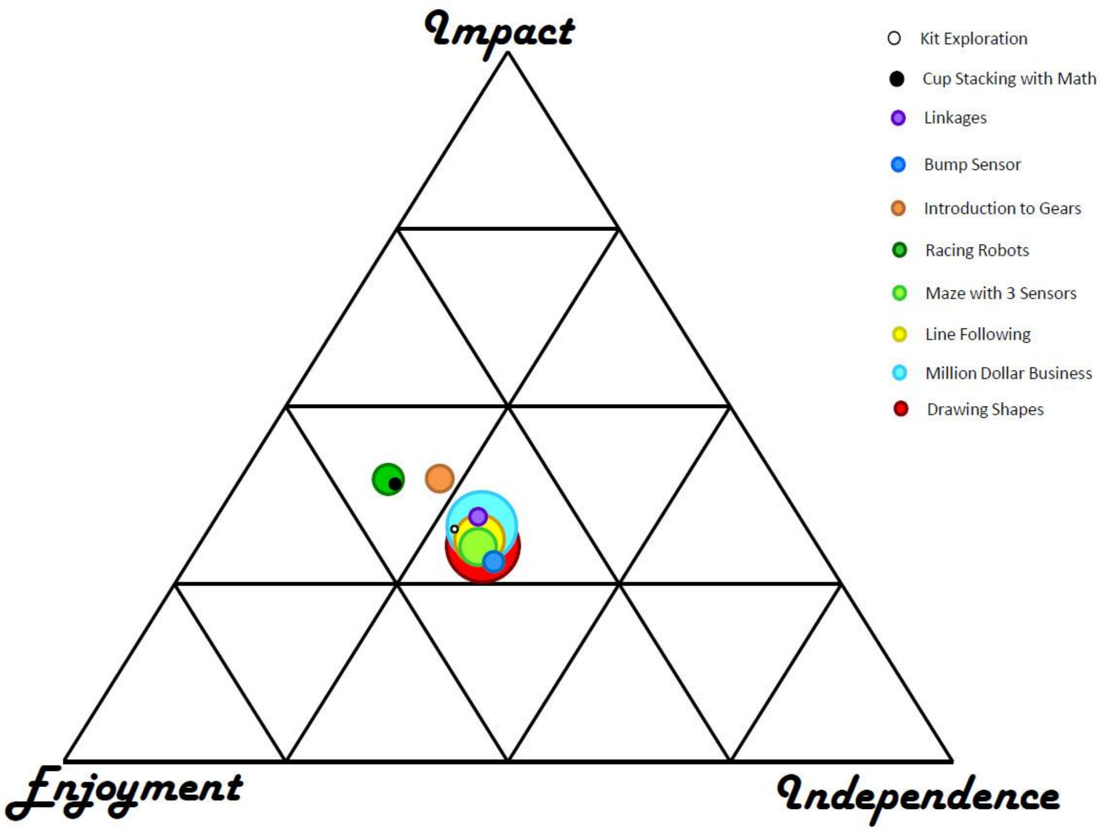

FIGURE 6: Weighted Ternary Plot of Categories

SUCCESS OF THE CURRICULUM

The final analysis results from applying the cut-off values for rating the success of activities (refer to Table 14 for more details) showed only two activities with collected data as failed: Linkages and Kit Exploration. Both of these activities failed in the Independence category. Four of the ten activities exceeded expectations, and the remaining four were successful. A full breakout is in Table 17 below. Eight out of ten activities was a very good rate, and showed that the curriculum designed over the course of the year was very successful in meeting all of the goals outlined by this project.

TABLE 17: Success Outcome per Activity

Activity	Failure	Successful	Exceeds Expectations
Linkages	X		
Kit Exploration	X		
Drawing Shapes			X
Line Following			X
Bump Sensor		X	
Cup Stacking			X
Maze with 3 Sensors		X	
Million Dollar Project			X
Introduction to Gears		X	
Racing Bots		X	

Table 17 above lists the activities in chronological order. Both the failures occurred at the beginning of the project. Collected data and feedback prompted the improvement of activity design, described in *Analysis of Written Mentor Feedback Comments*, and increased the success of subsequent activities.

ANALYSIS OF MENTOR/STUDENT RATIO AND ITS RELATION TO ACTIVITY SUCCESS

In the course of the iterative feedback and analysis, it was suggested that the ratio of students to mentors might have had an effect on the success of the activity. To determine if there was any correlation between the success of the activity and the ratio, graphs of both were overlaid on each other, shown below in Figure 7. The activity success graph shown is the fully combined graph, where all three respondent populations and all three categories have been summed, averaged, and normalized as described in the *Combination of Responder Populations* and *Combination of Categories* sections.

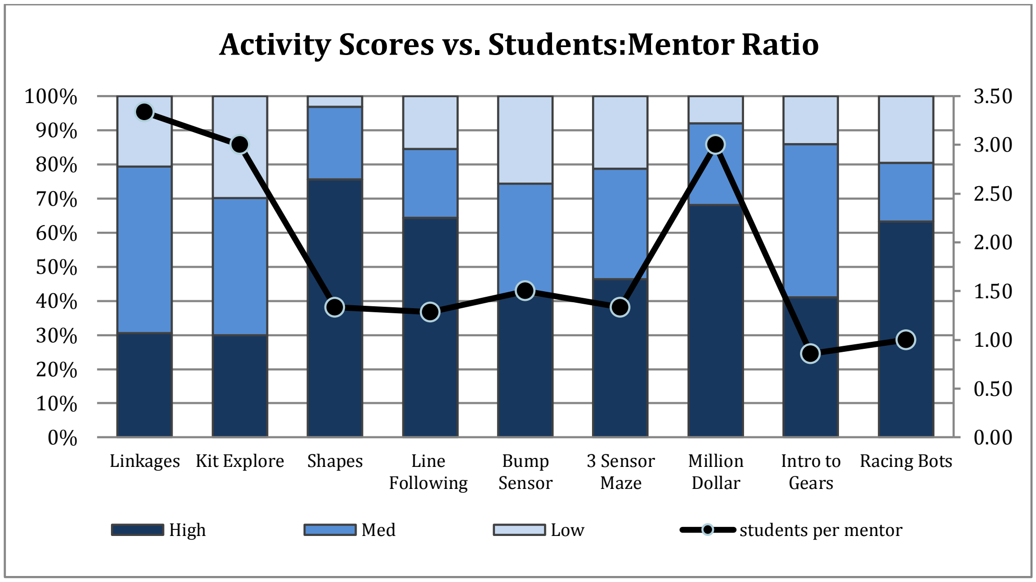

FIGURE 7: Combined Activity Scores and Student/Mentor Ratio

This graph indicates that there is no correlation between the exact numerical ratio and the success of the activity. Linkages and Kit Exploration were both unsuccessful but had the same number of students per mentor as the successful Million Dollar Project activity. The other activities also have varying levels of success for a similar ratio. These differences could be explained by variations in difficulty, the competency of the mentors present, the skill level of the students present, and other factors. These factors can be examined by analyzing the observations and feedback recorded by researchers and mentors respectively. The analysis, explained more thoroughly in the *Cross-Reference with Observations,* concludes that while the exact ratio has no correlation, the mentor presence is a crucial factor of activity success.

CROSS-REFFERENCE OF ACTIVITY FEEDBACK ANALYSIS WITH WRITTEN OBSERVATIONS

It is crucial for the sustainability of the club that they are able to design new activities in order to expand and vary the curriculum in future years and that these activities are designed in a manner to facilitate the purposes and goals that drive Robokids. The observational and written feedback data were analyzed and cross-referenced against the judgment of successful/not successful for each activity. By finding commonalities between activities with similar results, general recommendations were devised to guide the creation of new activities.

A. COMMONALITIES BETWEEN UNSUCCESSFUL ACTIVITIES

Activity creators need know what to avoid in their plans that would doom them to failure. Written feedback and observations were cross-referenced against the judgments of which activities did not adequately meet the goals of this IQP. Similarities were identified that were not present in successful activities. The most prominent traits of unsuccessful activities were unclear instructions and the inability of mentors' to adequately assist students.

Unclear or vague instructions left students feeling confused and frustrated. Linkages asked students to build four bar linkages using wooden craft sticks and brads, then to trace the coupler curve using a whiteboard and marker. However, nearly all the student feedback forms complained about the instructions given; they were confused and did not know what they were supposed to do[37]. The students did not know what a "successful solution" contained, and were therefore unable to make a successful linkage.[38] Kit Exploration started by asking students to

[37] Robokids
[38] Robokids

follow visual instructions to build a LEGO® base bot. The activity devolved into an open build session where the students could build whatever they wanted, after it became clear that there were not enough mentors to successfully guide the students[39]. The students were left feeling unsatisfied because the activity seemed pointless, especially when future activities with the LEGO bots focused more on programming than building. Rookie students were left frustrated by the connecting system used by the kits and were unable to produce anything they deemed an accomplishment. [40]Experienced students were bored and restless. [41] In general, if the students do not know what they are trying to accomplishment or what the point of it is, they will not enjoy the activity and will fail to invest any significant effort. This lack of effort prevents the students from demonstrating or gaining independence and will not result in any positive impact outside of the club.

While it was possible to compensate for a lack of mentors, a low number did negatively impact the success of an activity on occasion. If there were more mentors for Linkages, they could have explained to their group what the goal was and demonstrated an example of a solution. Working with small groups and conversing with the students also would have identified the confusion and frustration faster than the two mentors trying to oversee and work with all # groups at once. More mentors for Kit Exploration would have been able to work closely with the students to explain how the pieces connected and how to read the building instructions. A constant mentor presence per group, guiding the students with questions and prompting them for the next step, would have prevented students becoming bored and giving up on the activity. These difficulties could have been mitigated or overcome by more mentor assistance.

[39]Robokids
[40] Robokids
[41] Robokids

The students who participated in Robokids could be quick to judge and highly forgiving in equal measure. In general, very few activities were unsuccessful as hands-on fun and candy rewards overcame any minor negative feelings. The quickest way to sour the students' opinion was to create a confusing, frustrating, and unrewarding experience through poorly explained or vague problems that they felt were beyond their skill level.

B. COMMONALITIES BETWEEN SUCCESSFUL ACTIVITIES

Traits that were shared by successful activities, but not found in unsuccessful activities, provide a useful basis to guide the development of new activities. These commonalities were also found by comparing the different written feedbacks and observations collected. Features of a successful activity include an adequate number of mentors, clear instructions and goal, a solvable challenge, positive feedback, small groups, minimum lectures, and non-rote/non-repetitive, hands-on tasks.

A sufficient mentor presence and the need for clear goals and instructions are the inverse of the unsuccessful activities. When the students were able to focus on a clear endpoint and were given guidance where needed, they were able to successfully plan a solution. The realization of the solution was not even necessary. If the children felt that they were on the right track and were very close to achieving success, they rated the activity as highly enjoyable. The sense that they were on the "right track" was a product of identifying how the work they were doing directly related to accomplishing the goal. The identification came from the explanation of the mentors and knowing the end goal. This means that the presence of enough mentors to answer students' questions without prolonged delays and a clear end goal are crucial to the success of the activity.

A solvable activity, combined with positive feedback, is also necessary for students to feel as if they are on the right track, part of a successful activity. Solvable means that students' believe achieving the solution is within their ability. They are able to make visible progress towards a goal – even if they only accomplish several subtasks and do not complete the final end goal due to a lack of time. Accomplishing subtasks allowed the students to gain and demonstrate independence. Typically, the first subtasks the students accomplished were easier than the latter ones. Students were able to complete subtasks up to their level of ability and began to attempt ones that stretched and increased their independence level. This effect increased when the mentors provided appropriate positive feedback, which strengthened the students' confidence in their work.[42] Positive feedback solidified the students' belief that what they were doing was correct and increased their likelihood to repeat techniques and strategies in future activities without the guidance and feedback, i.e. their independence increased. Therefore, successful activities will be designed to challenge students without being overwhelming and positive feedback will encourage the students to bridge the gap between skills they know they posses and skills that are within their reach.

Smaller groups increased the amount of time students spent actively involved in the hands-on activities, which increased their engagement and motivation. In prior years, Robokids traditionally split students into groups based on the number of resources available. It was difficult, if not impossible, to involve the students in build or programming, causing long idle periods while students had to wait their turn. This frequently caused restlessness and boredom, which resulted in students checking out from the activity and running about the room. Splitting students into groups of 2-3 kept the majority of students involved and actively working hands-on

[42] Robokids

for the entire duration of an activity.[43] Additionally, mentors more effectively guided and prompted experienced students to teach newer students, which prevented the experienced student from becoming bored or frustrated with their partner(s). All the students cared more about the product they were creating when they were more involved, which meant they were more engaged and more invested in the work. When students were invested in the work, they were more likely to ask and respond to questions, which increased the knowledge they learned and increased their independence level. This shows a clear relation between small group size and the overall success of the activity in meeting project goals.

The decreased group size increased the number of mentors required to achieve a 1 mentor per 1 group ratio, but this was not necessary for all activities. However, smaller groups meant the chance for all students to be actively engaged at once, reducing the difficulty of managing the same number of students. Mentors could let one group work and answer the other group's questions without worrying that students would act out for lack of a task. This factor partially explains the lack of correlation between the student to mentor ratio and the success of the activity.[44] Activities where students had less questions could be successfully managed by fewer mentors than more difficult activities where students had many questions.

The observations and feedback confirm the advice from expert knowledge sources to minimize lecturing and direct teaching. The students were highly aware they were not in a classroom setting and that their presence was voluntary. Subsequently, they were highly sensitive regarding any characteristics they negatively judged as too similar to school. When the explanations were longer, the mentors had to work harder to recapture the students' interest and

[43] Robokids
[44] Robokids

attention.[45] The students' reactions to learning were more favorable when they "discovered" lessons through their hands-on work that would have alternatively been taught directly or when the lesson was explained by the mentor in response to a question initiated by the student. Allowing them more time to work also directly relates to their engagement, investment, confidence, belief that they are on the "right track", and ability to approach a solution which all improve enjoyment, independence, and impact.

Finally, as alluded to, the need for compelling hands-on activities that avoid rote or repetitive tasks is a crucial underlying feature to nearly all these activity traits. Hands-on activities involved the students to a greater extent, required that they were involved and asking questions, and increased their investment in the activity. This level of active involvement required that the activity demanded enough effort (non-repetitively) to prevent boredom or "checking-out". Most fundamental of all, hands-on activities were fun. To interest and involve the students, it is crucial that as much of the activity is as hands-on as possible, without becoming dull through repetition. Successful activities include a low student to mentor ratio, clear instructions and goal, a solvable challenge, positive feedback, small groups, minimum lectures, and non-rote/non-repetitive, hands-on tasks. These features all increase the enjoyment of the students; facilitate the growth of their independence by shrinking their Zone of Proximal Development; and result in a greater impact on the students' which will follow them beyond the limited periods of the activities.

[45] Robokids

C. DIFFERENCES BETWEEN SUCCESSFUL AND HIGHLY SUCCESSFUL ACTIVITIES

Any motivated leader will be interested in going beyond merely successful activities to highly successful activities. However, these nuances were more difficult to capture, especially within the limited period to collect data. The collected data, feedback and observations often implied there were intangibles that may affect the success of the activity. These intangibles may include the mood of the mentors which may have depended, for example, on the proximity of Finals Week; the mood of the students which may have been a result of the weather, the lunches served in the school cafeteria, or delays in transportation; and/or different perceptions on the "coolness" of the activity by mentors and students which remained an elusive pattern. One crucial tipping point between successful and highly successful was identified: how much time was allotted for an activity in terms of how close students were to a solution.

The "tipping point" is an addendum to the solvable principle, which states that while students did not need to fully complete the activity for it to be successful, they did need to feel that they were close to a solution. In the case of the Bump Sensor activity the students had only 1 hour instead of 2 to work.[46] The students were not able to make significant progress towards a solution, especially compared to their progress on the highly successful robot-based activity Drawing Shapes.[47] The students felt frustrated over their perception of the distance between them and a solution, which lowered the rating of the activity. It is difficult to judge ahead of time how long an activity needs to pass this threshold. Several years of Robokids experience has shown that between 90 minutes and 2 hours is highly successful for the robot-based activities included in the curriculum, whereas 1 hour was insufficient.

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[46] Robokids
[47] Robokids

A potential avenue for future research would be to utilize the principles found by this report to design more successful activities and thereby collect a greater number of data points that could be used to compare successful versus highly successful activities. A greater number of data points could identify trends with greater accuracy and improve upon the design principles to create an even more effective curriculum.

D. FACTORS THAT DO NOT AFFECT ACTIVITY SUCCESS

Comparison between the evaluated success of the activity and collected feedback and observations showed that there was less correlation between some activity traits and the activity's success level. The two main factors that were expected to have a greater effect than shown were the student to mentor ratio and the ability of the students to fully complete the activity. As previously discussed, the specific numerical student to mentor ratio was less critical than the mentors' ability to answer questions promptly, provide positive feedback where appropriate, and maintain classroom management. Depending on the students, mentors, and difficulty of activity, the ratio needed to satisfy these conditions varied. The need for the students to fully complete the activity was less important than the students' belief that they *could* complete the activity. These relations provide more flexibility in the design and execution of the activities, increasing the ability to adapt the lesson plans to situations as needed.

4.6 ANALYSIS OF "GENERAL" SURVEY

The responses to the "General" survey allowed obtaining a general perception of the Robokids afterschool program at its midpoint based solely on the children's opinion. More importantly, this survey served to determine the children's interest to be exposed to STEM-related activities and whether or not the Robokids program was being able to match their interest levels.

CHILDREN'S GENERAL PERCEPTION OF ROBOKIDS AND THE PROGRAM'S ABILITY TO MEET THEIR INTEREST LEVELS IN STEM

From the general survey administered to the children (Appendix 11.A), a general perception of the Robokids program was obtained based solely on the children's opinion alone. This general perception, Figure 8 (representing the information on Appendix 13.A, which comes from Table 10 previously discussed in the Methodology section), shows that while the high rankings for the STEM categories were not all above 50% midpoint, the combination of the high and the medium rankings were above 65% for Science, Technology and Engineering; however, the combination of high and mediums rakings for Math did not even reach 50%. This result is due to the survey administration occurring prior to the implementation of the two major math activities: Cup Stacking and Million Dollar Project. This shows that even at the very beginning of this research study and middle of the yearly program, when only few activities had been implemented, STEM outreach was apparent for three out of the four STEM areas. Other essential factors that would influence the proper design of the Robokids curriculum would be Enjoyment, Learning, Variety of Activities, and Motivation to Attend. The success of this newly designed Robokids curriculum depended highly on the level of Enjoyment experienced by the children because otherwise they would not be willing to participate in the program, meaning that the Motivation to Attend would decline as well. This Enjoyment is proportionally related to the Variety of Activities. If there is no Variety of Activities, the program would appear boring and children would not be interested in it. Similarly, the Learning experience was an essential aspect to be achieved since, as stated in the goals of this IQP, this Robokids curriculum is expected to promote self-motivated learning experiences for the children. All these four categories of evaluation obtained above 70% for the combined high and medium rankings. This indicates that, according to the children, the Robokids program created a fun, learning environment with a satisfactory variety of activities that motivated them to continue attending Robokids and learning about STEM, which were two of the main goals of this IQP. Another main of goal with the development of this afterschool curriculum was to supplement the STEM materials covered in school through activities that require children to apply the gained knowledge to solve specific problems. The very last column of Figure 8, shows that the combined high and medium rankings scored above 60% for the Compatibility of the activities performed at the Robokids program with the materials learned by the children in school. This indicates that, according to the children, the Robokids program was able to cover and expand on the materials that the children were taught in school, thus increasing the expandability of the program and making it more easily adaptable for teachers to use incorporate the activities in their lectures if desired, which is part of the goals of this IQP.

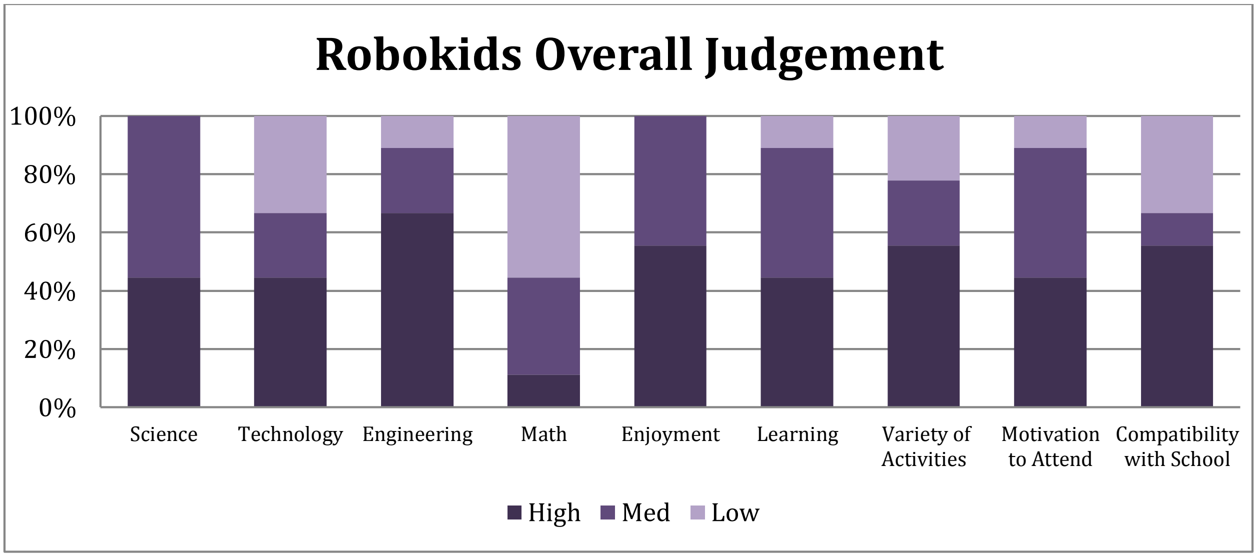

FIGURE 8: Robokids Program General Perception, based on the Children's perspective

In addition, when the children's interests to be exposed to STEM-related activities were compared to the STEM outreach of the Robokids program as explained in the Methodology section, the combined high and medium rankings of the children's STEM interests for Science, Technology and Engineering were fulfilled by the Robokids program, Figure 9 (representing the information on Appendix 13.C, which comes from Table 12 previously discussed in the Methodology section). This fulfillment was achieved only when the combined medium and high rankings for the Robokids outreach either equaled or surpassed those representing the children's interest levels for each STEM area. In the case of Math, there was no question in the survey prompting the children to reveal their interests within this specific area. At the time that this survey was administered, the two main Math activities (i.e., Cup Stacking and Million Dollar Project) had not been conducted yet. This explains why the combined high and medium ranking for the Robokids program's Math outreach scored less than 50%. This data indicates that, according to the children, the Robokids program was able to fulfill their interest to be exposed to hands-on activities within the different STEM areas. This was essential to meeting the goals of this IQP since not meeting the children's interest levels in STEM would cause activities to not be sufficiently engaging and impactful, and thus not as effective as intended.

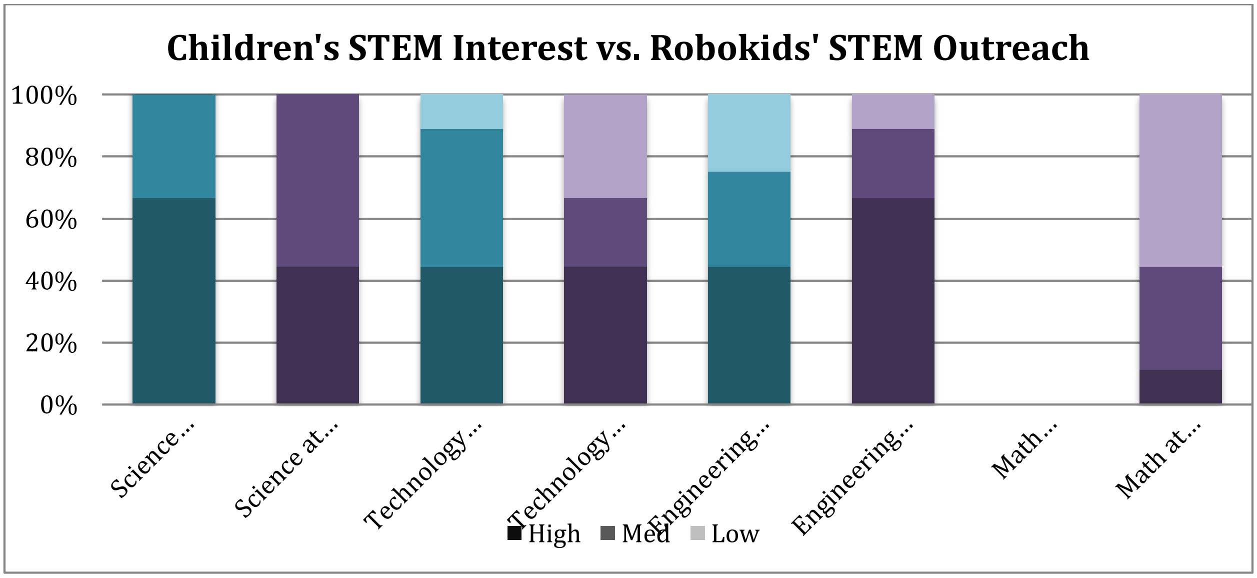

FIGURE 9: Children's STEM Interests compared to Robokids' STEM Outreach, based on the Children's Perspective

Overall, the general survey administered at the beginning of this research study showed that, according to the children, this newly designed Robokids curriculum was showing satisfactory signs of STEM outreach while still creating a fun, learning environment with a satisfactory variety of activities that motivated them to continue attending the program and learning about STEM. It also showed that, from its early stages, this Robokids curriculum appeared to compliment the materials covered in school, thus expanding the learning experience of the children. Lastly, this survey indicated that the Robokids program appeared to meet the children's interest levels in being exposed to hands-on activities in three out of the four different STEM areas while leaving room for improvement as time progressed and more activities were conducted.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

This project demonstrated that well-designed, well-planned, and well-executed activities that are fun and challenging at the same time successfully motivate students to learn and develop their skills. STEM-based activities provide a natural medium for this as they provide a natural balance between fun, learning, hands-on experience, and discovery. As students grow up in a world increasingly saturated with technology, it is critical that they have some appreciation for what STEM is, where it is, and how it affects their lives, and hands-on activities help to develop that sense.

The design principles derived from the collection and analysis of expert knowledge and the modifications made during the course of the project based on iterative analysis were able to create a successful curriculum of activities that were enjoyable for students and mentors, increased students' independence, and impacted student participants beyond the bounds of the club. Cross-referencing design principles, quantitative feedback, and written feedback/observations were able to identify trends between successful and unsuccessful activities to guide future lesson plans.

There are other valid ways the feedback data could be merged, sorted, and compared in addition to the forms of analysis attempted and dismissed due to infeasibility, lack of data, or lack of meaningful and relevant conclusions, and forms utilized and fully completed. These valid alternatives were not completed due to time restrictions on the project and did not appear to significantly impact the project's conclusions. The results obtained from the analysis make logical sense and agree with the subjective opinions of the researchers and veteran mentors of Robokids. Other possible avenues for future research include extended collection of data to better determine differences between successful and highly successful activities or analysis of the activities through the lens of more high-level educational theories such as Papert's Constructionism.

DELIVERABLES

Upon completion of this IQP, researchers were able to develop a total of seventeen lesson plans for different activities that can be conducted during the Robokids afterschool program sessions. These lesson plans were all tested and modified depending of their effectiveness in order to guarantee an optimal balance amongst the three categories of evaluation of success previously established: enjoyment, independence, and impact. All lesson plans and their corresponding instructions for proper use were produced, tested and modified by the researchers of this IQP. The full collection of these seventeen lesson plans can be seen in the How-To Guide at the end of this report.

A design guide was also written with clear instructions on how to produce lesson plans similar to the ones included in the new Robokids curriculum developed as part of this IQP and how to modify them if necessary. Details regarding this How-To Guide are covered in the following section. The full How-To Guide booklet is included at the end of this report.

An official website (http://wpi.orgsync.com/org/robokids/home) was created for the Robokids club to facilitate the recruitment of new mentors and to promote the goals of the program. All lesson plans and the How-To Guide were made available to greater WPI, Worcester Public School, and the English-speaking Internet communities through this website in an attempt to give back to the community by making this IQP's findings accessible to anyone interested.

All deliverables were also made available to the STEM Education Center at WPI for their distribution to other educational institutions interested in using them.

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APPENDICES

APPENDIX 1

A. UNDERGRADUATE SURVEY

What was your favorite STEM class in middle school?

____

What was your favorite STEM class in elementary school?

____

What was your favorite STEM –related club or extracurricular activity?

____

Describe your favorite STEM-related activity when you were in elementary school:

____

Describe your favorite STEM-related activity when you were in middle school:

____

B. UNDERGRADUATE SURVEY: RELEVANT, USEFUL, NON-DUPLICATE ANSWERS

Answers verbatim from survey.

1. ELEMENTARY SCHOOL ACTIVITIES

1) "In the second grade we each were assigned a dinosaur (something lesser known, not a T-rex) to write a report and present to the class about. The part of that class I still remember is all of us making a large box/fort time machine type thing that was supposed to represent the different time periods the dinosaurs lived."
2) Egg Drop.
3) We were able to build our own machine out of materials that we brought from home. Then we listened to each group's presentation of what they built using different parts talked about in class.

2. MIDDLE SCHOOL ACTIVITIES

1) We built rockets out of cardboard, craft paper, and toilet paper rolls, then attach a low-powered hobby rocket engine inside (like the guts of a firework). We launched them in turn and measured which designs went highest and furthest.
2) Experimenting with laser beams and reflections in physics class.
3) The million dollar project. Our teacher told us we had a million dollars to spend and we had to spend it all down to the last penny. We needed to show every penny we spent all

done by hand. If we bought a computer, we needed to calculate tax on our own. We were giving limits such as we couldn't spend more than $100,000 on cars, $750,000 on a house or donate more than $50,000. We also needed to have at least 20 items, 15 of which needed to include tax. We had to organize it all in a portfolio with pictures and what we were using a particular item for. Most people stayed with a theme, such as they were opening their own bakery and had to purchase the building, the machines, the supplies etc. Everyone in my school waits for this project and really go all out on what they would do with a million dollars.

APPENDIX 2

A. CATHERINE COLEMAN'S INTERVIEW QUESTIONS

- Did you have any previous experience with working with children that was helpful when you started running the Robokids club? What did you learn from that experience? How is Robokids the same/different?
- How did you balance showing and explaining with hands-on doing?
- What keeps the children the most interested and engaged?
- What types of activities did you do?
- What about Robokids could be improved to make it more effective?
- How long did your activities usually last? Why?
- Were you aware of the 2010 Robokids IQP? Did you ever use the curriculum they developed? Why/why not?
- Did you teach the college volunteers how to help the students? If yes, how?
- How much did you usually spend on materials and supplies?
- What activities would you have done if money wasn't an issue?
- Is there an optimum ratio of college students to children?
- How did you decide if an activity was successful or not? / How did you decide if you would reuse an activity?

B. CATHERINE COLEMAN'S INTERVIEW TRANSCRIPT

- **Did you have any previous experience with working with children that was helpful when you started running the Robokids club? What did you learn from that experience? How is Robokids the same/different?**

So I actually do have experience working with kids before Robokids. My mother loves to do lots of science experiments in classrooms. However, as I grew older she then was like "Cat will come along and be my helper." So I've actually taught several middle school classes, like in high school. My mom would all the time, she would actually pull me out of high school, and be like "Cat, I'm busy right now. Just pretend to be me, go to the classroom and do this assignment." In fact, afterwards, the teacher would tell like, they would get reports back from the kids, that I did better than she did in many of the activities. We do like chemistry, and science, and soap-making, and all sorts of different things like that. So that's one of the experiences I have. Um, I did a lot of after-school programs when I was in high school for kids, teaching them… entertaining them. I had a lot of things where I was told to entertain a large group of kids. For example, one time, I coordinated the largest food fight that Glenridge middle school has ever seen. They stuck me in a room with 400 kids and then had a meeting with their parents in the auditorium. Yeah. They were like "just entertain these kids for 3 hours" and then left me. They didn't tell me they were going to do this. So um, I coordinated a food fight because I was in the cafeteria. I made teams, we had lines and boundaries and rules. We had refs. If you're going to have a food fight, so have to make it VERY legitimate. Let's just say they were highly entertained for the entire three hours.

- **So overall, if you have had advice about how to work with kids?**

Keep changing activities. Don't ever do anything for too long because they'll get bored of it. Quickly. So you have to keep changing activities. If you're going to talk, and explain things, never talk or explain things for longer than 15 minutes otherwise their attention is out the window and you'll never get it back. Um, my favorite thing to do when getting kids' attention, I'll go "If you can hear my voice, clap once. If you can hear my voice, clap twice…" It is the most effective thing I have ever seen in my entire life. That one I've found is the BEST. It's my favorite, my favorite trick for getting kids' attention.

Robokids is different because it is consistent, while the other things I've done, like teaching kids programming, has usually been a one-time lesson, one-time seminar, where I only have to make up one lesson plan.

- **Does that change how you work with the kids, if you see the kids repetitively versus one time?**

Yeah. With the one-time thing, I usually take all I have on that subject and shove it all at once and just keep them super interested and do lots of different little activities and just keep moving as fast as I can. In which case if a kid gets lost, we're only on an activity for a short amount of time and it's okay. With Robokids since I keep seeing these kids, I spend a lot more time on each activity and I make sure that everyone understands and I kind of drag it out a little more than these one-time seminars and lectures.

- **How did you balance showing and explaining with hands-on doing?**

So the first year when it was all based on LEGO Mindstorms I actually would… When I first took it over, it was actually a lecture for the first hour and then doing for the second hour. It was bad, really bad. So they'd talk for an hour about a subject and then the second hour would be hands-on. So, under Sabrina, I did several lectures like that, where I had my one hour lecture where every 5 minutes we had some sort of hands-on thing. I'd have a lecture up and then be like "Okay! Group activity!" And they'd do something small that had something to do with what I was talking about. And that worked actually, really well where I never had my breaks go longer than 5 or 10 minutes in between and I was able to keep their attention for the full hour unlike most of the presentations that the other Robokids members did. Which were bad.

- **What about now, where we no longer have the one hour lecture? Do you explain first and then have the kids do things or do you do things and explain while they're doing things, or after they're doing things, or something else?**

In the years, I've actually done both and tried both. Sometimes if the kids are extremely unfocused, I'll throw all the material at them and be like "Do it!" and then after they've done it I'll be like "okay, well let's talk about what this means." For example, with the shapes: I had them cut out the 3D shapes. I had them all cut out, do it all together, and then after they'd done the activity, I was like "Okay, what does it mean? Why is this significant? Why did we waste our time cutting these out and smushing them to bits?" So, and while on other ones, like the programming , it'll be like "okay, here's the program, here's how it works, does everyone understand? Okay, now let's go." And depending on the activity both can be successful.

- **What keeps the children the most interested and engaged? You mentioned hands-on activities, but are there certain types of activities?**

Activities where each kid is doing their own thing, I found actually keeps them the most engaged. Unlike, WPI, you know we're like "oh small groups" you know, sometimes small groups are nice because the kids can help each other but they are… they haven't reached that stage of development or maturity where helping each other is a high priority. And I found that as many activities as you can where each kid has their own project, has their own results – and then if they need to they can ask the kid next to them – keeps them the most engaged.

Oh, I did cup stacking. I actually took a bunch of cups, 4 sets, numbered the bottom of them 1-100. So then I had the kids stack the cups, so then I was like "only use cups that are a multiple of 3" so they had to find all the cups and then we'd check them and then the first team to get it done… And I did a bunch of, so they had to stack the cups upside-down and right side up in multiples of 3, and then it was like math skills and things like that. For that activity I gave one kid a Dixie cup and I got jelly beans and every time, so then the fastest team got 3, the next 2, and then next 1, and then by the end they all ended up with a huge cup full of jellybeans from all the different little activities they did.

- **How long did your activities usually last? Why?**

Activities shouldn't last more than an hour. They really shouldn't last more than 45 minutes where you have 45 minutes of activity and then you have like a 10 minute wrap-up of let's look at everyone else's projects, let's do the competition. And if an activity is extra-long, putting it where you have that break in the middle really helps. When I first took over, the dinner break was at the end. So you actually would talk, and then you'd do the activity, and then 10 minutes before it ended they'd eat and rush them out the door. And then this revolution came to me and I was like "Wait a second, this is a good break." So yeah, it was that for awhile and then it degraded down when people stopped signing up for days, they didn't know what to do. So what Sabrina would do is she would go onto FLL, find a mission… oh no, no, no, that's not what happened… She would have a day where she would explain ALL of the FLL missions to them. Yes. She just sat down and explained the entire board and the entire mission, and the next week she'd go in and be like "Okay guys, which mission do you guys want to work on today from the last one?" And they'd be like, "…?" And she'd like name 3, and they'd be like "That sounds good". So then we would then work with the kids for two hours on whatever missions they felt like. So different teams could be working on different missions. And then the next week, we would just continue that, with the same three groups, and there was never the same kids, and the goal was that they would compete in a FLL tournament. So, that didn't work. So yeah, having a 2 hour activity them working on it, by the end, usually by the end of the first hour we'd have kids running around in circles, screaming their heads off. We had kids in the back texting on their phones. At one point the Friendly House people collected all their phones before they walked in because of how bad the texting got. It was bad.

- **What about Robokids could be improved to make it more effective?**

So one thing we've always struggled with is keeping it engaging for the college kids, making it so that college kids want to come back, and want to help, and are reliable, and also just that they… even getting them to show up early and help us out and get the plan and get on the same page as us is something we've never mastered. And we don't really have a good system for it. When I first started, Sabrina's system was on the very first time she assigned us each to a different day and we were in charge of that day and we could do whatever we wanted for that hour lecture and the hour activity. And, it did make you show up on your day but it wasn't a very good system because you would only show up on your day and then you didn't really want to help with anyone else's activities because you weren't informed. We tried things like after every Robokids we had a ten minute meeting where everyone as a group would reflect back on how the Robokids went: if it was good, if it was bad, what changes we'd like to make, what we'd like to do next week. Unfortunately, now that I have grad class, both this year and the end of last year, those meetings stopped happening.

- **Did they work, while you had them?**

I think they were good. Especially when I was able to assign things to other people, they usually came through. I'd usually assign them to "Can you get this done by Tuesday?" and then if they didn't, I had Wednesday to pick up the strings and make sure we had a good curriculum ready for Thursday. So I think that is something that could help and should help, especially in getting their ideas on how to make it so that they want to come back.

- **Were you aware of the 2010 Robokids IQP? Did you ever use the curriculum they developed? Why/why not?**

So I had heard that there was an IQP. Because the IQP was originally Three's, Three didn't complete the IQP, Sabrina picked up where he left off, and then I picked up where Sabrina left off. I have never seen it. I don't even know if they have a hard copy, I don't know anything about it other than it existed, and it was Three's project and it never got finished.

So Three was the guy who started this project in… 2008? He started it in 2008 or 2007, it might have been 2007, his IQP. He started it then, he started the program, the program got started in 2007 or 2008, and then it continued under him and Sabrina, and then he… it was one of those IQPs that just never end. Then he got suspended from school in 2009, he got suspended for that school year so he wasn't here, and then in 2010 I think he briefly came back, submitted what he had, which is why it counts as 2010, and then transferred to different school. He submitted it so that he could get credit for the progress he had already done. So ever though it's called the 2010 IQP, it was started in like 2007.

- **How much did you usually spend on materials and supplies?**

Because this club's never had any budget, I've bought everything out of pocket myself, I bought candy every week, which averages about $5, I buy whatever supplies I felt like. So dowel rods, peanut butter, everything like that. I think that in, that I would average about, I would say about $12, because some weeks I didn't spend anything and then some weeks I spent like 30 bucks. So I'd say that I spent about $12 a week on Robokids.

- **What activities would you have done if money wasn't an issue?**

If I had like a real budget, there were a lot of activities I wanted to do, but I didn't personally want to spend that much money on because I was already spending so much on the club as it was. Like I wanted to do a lot more circuit stuff, getting the supplies for that would have been difficult. I'm really excited we're applying for that now. And I like your idea of buying kits that the kids can actually play with, 'cause we're stuck with the NXT kits and they are SO hard to use. I also kind of wanted to do box cars where, you know, you have the cars and you weight them and look at how far they go and things like that. I kind of wanted to do that but I didn't, of course, have the supplies. So something else I also thought about at one point, I had a girl involved in the program who was into BME, chemistry stuff. And she kind of wanted to do things like create slime and they could bring it home and I was thinking that's kind of relevant, because there is engineering and science in there and some of her ideas were do slime… Um, you can actually do soap-making in a classroom. My mom's done it before. Another thing that I thought was really fun that we've done roller coasters where you can actually buy foam Us and buy marbles and do loop-de-loops and figure out how big of a loop-de-loop you have based on the height, and we'd actually teach the kids the basics of the math behind it and then we'd have them build their own roller coasters. I just couldn't, didn't want to buy the supplies for it. So we actually got a thing, mounted it on the wall, taped that, and then were like "okay, here's your start point" and we had several start points and several different groups and these tubes you just put a piece of duct tape on the bottom [to attach them] and the marble just went through and it was a great time. So we did that for a physics class.

- **Is there an optimum ratio of college students to children?**

So, the reason Sabrina quit is that we originally had this advisor in the history department who was on the board of Friendly House and he actually cancelled robokids on us several times and his reason for it was he believed there should be a 1:1 ratio and whenever we didn't have a 1:1 ratio he would cancel it. Like if he ever found out that we didn't have 1:1 he'd be like "oh yeah, not enough students, we're cancelling" and that's not good. It really depends on the activities. If you have an activity with groups, I believe 1 mentor per group is great. If you're doing a lot of activities where each kid has their own thing 1 mentor for every like 3 is pretty good. Remember we did that linkages thing? I think we had 1 mentor for every group of 3 kids, that would have been really great.

Also, we only get 3 laptops from the ATC. If there's another way we could get more laptops I think that would… It's the maximum they're willing to give us consistently. Like we can request more specially, like 5 on certain days, but because we're a regular club and the goal of the ATC is not to service things like that, it's supposed to be like for special occasions to check out stuff, they need to have a certain number available. I don't know if we could look into the Help Desk, or the ATC, or maybe some other club that has laptops, I'm not really, I don't have a good solution, but I think if we had more laptops we could have more groups. The reason I even got 3 is that we had 4 robot kits, we used to have 1 kit we demonstrated stuff on and the kids would use the other 3 kits. Then we had it where we had 4 kits, but we only had enough stuff for 3 kits at which point there's no reason to get more laptops than kits and I actually had to do a lot of paperwork to even get those 3. I went, requested them, they said no, I had to get a special letter from Stafford in which case they were like "you need to come in and justify this" I had to get 2 letters from Stafford to even get 3 laptops regularly.

- **How did you decide if an activity was successful or not? / How did you decide if you would reuse an activity?**

So it used to be based on the 10 minutes meetings we had. If the kids paid attention. If we didn't have incidents of the kids going crazy or wild or losing our voice it was considered successful. Also, if we believed that they learned something… The biggest factor was did we have any kid go crazy? That gave it points down. If we could never get their attention, that was points down. If anyone lost their voice, that was points down. Just, if the kids seemed interested, it was successful regardless of how much they learned. If they were quiet, even if we didn't have enough supplies, if they at least paid attention for the one part they seemed like they wanted to do this activity even if there weren't enough supplies for it.

- **Anything else you'd like to say?**

This club is difficult on the people who run it. And the people who want it are going to want to have days where they say "I don't want to do it today", no reason, just "I don't want to do it today" and for that reason you should have two people at least who are in charge and can handle it completely on their own, and those two people trade off and the other one doesn't have to be there, just because of all the stress that's involved in the club.

APPENDIX 3

A. TEACHER FOCUS GROUP / INTERVIEW QUESTIONS

- What grade(s) do you teach?
- What is the general academic standing of your students?
- How large are your classes?
- What subject areas do you teach?
- What is the best way to handle a rowdy student?
- How do you practice classroom management?
- How do you hold your students' attention?
- What are some methods of engaging the students?
- Generally, how long do you ask students work at a single task?
- What tasks are given longer time allotments and which do you keep short?
- What are the advantages/disadvantages of children working individually? With partners or in small groups? In larger teams?
- Does competition help motivate students or does it detract from the lesson?
- What is the first step you take when designing a lesson plan?
- What are resources you use when designing a lesson plan?
- Are the MA standards related to Science, Technology, Engineering, and Math reasonable and appropriate for your students? Are they too easy? Too advanced?
- What subject material do your students enjoy the most? Least?
- What types of activities do your students enjoy most? Least?

- How do you evaluate what your students' have learned?
- What is the best casual method of evaluation without tests or quizzes?
- What would you particularly like to see students do in a STEM-based extracurricular?

B. MIDDLE SCHOOL TEACHER FOCUS GROUP TRANSCRIPT

Carly: We're both undergraduates at WPI. Part of the WPI graduation requirements is that we do an interactive qualifying project which is a social science based project so engineers have some idea of social issues and how to engage with society. There is a club in WPI called Robokids. Each week a group of about 16 kids between the ages of 7-15 come to WPI for 2 hours. We do a bunch of stem-based activities for them: building, some programming, all kinds of random general activities. The one we did the other week, we showed them how vacuum grippers work by putting them in trash bags, and sucking the air out and trapping them. In the past years, it's been running since 2006-2007, it's been very slap-dash, and it's just whatever the college students do like "Oh we'll do spaghetti marshmallows today"; there's not really a plan. So our research plan is to figure out how to design a curriculum that will be more engaging for the students so that we can actually try to teach them something beyond something that just amuses them, to try to teach and engage them.

Robin Scarrel: We're trying to figure that out ourselves.

Carly: We figure you guys know better than us though how to work with kids, so, I passed out a list of questions that kind of shows the information that we're looking for. You know, so we'll try to ask the questions or build on something, feel free to do so since you guys might have a better idea what we need to know than what we do. If we hear something really interesting we might ask you to explain more. But other than that, it's really just a conversation, so this is our first focus group, so, we're trying to figure this out as we go along. To start if you guys could go around the table again, I think the first 4 questions it's what you teach, what grades you teach, your names, also if you wish to remain anonymous, if you don't want your name included in our report say that as well. Report will be uploaded to the WPI library database online where it will be searchable for a couple of years. So if you don't want your name published that's fine, we'll remove it. Otherwise we might quote you or use quotes in our report. So, yeah, if you want to start.

Robin: My name is Robin Scarrel, I teach 7th and 8th grade science at Forest Grove. Classes are anywhere from low 20's to mid 30's, and the classes can range from about 30% in most clusters are honors students, the rest are non-honors students and that degree of variation is very wide.

Matt: My name is Matt, I'm an 8th grade science teacher. And classes are about the same, I would say range from the mid 20's to low to mid 30's. My particular cluster we call that group clusters whether it's science, math, English and social studies teachers that are paired together. Does not have any honors classes, there's one large what we call ELL, English language learner classroom, we have a learning disabled classroom, LD, we refer to that as classroom. Then 2 other classes that are non honors classes. And a general academic standing, it's not so good right now. But, moving on.

Argerius: Hi my name is Argerius, I teach Forest Grove science, 7th through 8th. There is 25 students, 2 honors, one inclusion, and one college. Both classes honors class, one is high end and the other in between. The college class is all year round. 20 percent second language learner, and 80 percent are maybe level 5 or level 4.

Robin: Which means that they weren't yellow, the students.
Ann Marie: Hi my name is Ann Marie O'Han, I teach 8th grade science. Basically I have the same thing as what Robin had said about the class size classes, but they are actually mid 20's to high end of 30's, 35 and 36 in classroom. They range from honors groups to groups that have inclusions kids that at some times very very low. Some of them are not so very low. It depends on the mix and they have a college level group that like Matt says is a general academic and then I do have some honors group that have some fairly good skills.

Sue Martin: My name is Sue Martin, I teach 7th grade science. My class size is high 20's low 30's. I have 2 honors classes that make about half my students, and then I have an inclusion class that have many students in it that have special ED plans. It's a large class, it has 31. And currently I have an aid that is helping me that started a few weeks to assist with the inclusion class. The other class is a college class with about 30 students in it.

Paula: I'm about the same, I'm Paula Halligan, and I teach 7th right now at Forest Grove. I have 4 classes at College level, all at about 30 per class. High percentage of English language learners, and a high percentage that are below proficient in their spectrum.

Shawn Keeting: My name is Shawn Keeting, I'm a special ED resource room teacher. I teach multiple subjects. 2 social studies and 2 science class. My science class is 7th and 8th. One is 8 kids the other 12. Obviously they're resource room, ranges from about grade level with some of them to below grade level. We follow the general science curriculum for 7th and 8th grade.

Carly: So our first couple of questions, classroom management, how do you keep the kids mostly paying attention and keep them from acting out?

Shawn: This year I kind of did things differently, I did some reading over the summer, what do I need… my goal is to find out what I needed to do. To have a student change, I change, I'm really happy with the results so far. I told them early on the year for the 1st 10 weeks that I needed to earn their respect, and I kept on pushing that until it was ingrained in them about earning their respect. And I became more patient with them. I out waited them plenty of times. And it was more positive reinforcement and them understanding who they are at that age. The biggest thing was earning their respect, getting their respect first before I can give it to them. That was the biggest change for me. And understanding where they're at, academically, behaviorally, knowing more about their background, knowing more in-depth about their IP, generally understanding them much more, accepting where they're at but also I have them accept the fact that there's plenty of growing they can do. That was the biggest thing for me that's worked.

Paula: To piggyback on what Shawn was saying, students at this age group have very little automatic respect just because you're the adult. And you say "This is going to be fun, we're going to do this" and you're going to learn that doesn't wash. So what Shawn was saying was about respect and a lot of times especially in this situation where you are going to be working with them, speaking their language, being flexible, and sparking interest and having provocative questions to challenge their thinking and is interesting. That's the main thing that keeps their attention, is interest.

Matt: If you have a individual case with a rowdy student, the first thing you do, you redirect. We want to get that kid, sometimes you want to rely on nonverbal with a look, but if that doesn't work then you kind of do a little teacher proximity. Go over there, give them their paper, "this is what you're supposed to be doing", get them redirected. Some kids as you know you need to redirect every 2 minutes, others just one look is all they'll need. Am I right?

Paula: But yelling across the room at them doesn't work.

Shawn: And sometimes it takes a while to learn that it really doesn't work. They respond to softness most times. Another thing, with our school, everything is more or less streamlined, everyone's on the same page, we know what routine we're in from [muffled] minutes so they know what they have to do by 10 weeks. So that when they come in, they're robotic, they know they have to get their notebook…

Paula: Routine.

Shawn: Routine. And I think that's a big part of the school focus. And another thing is that I don't allow them to opt out, opt out is not an option. If you say I don't know for an answer, "Ok, then I'll come back to you, and Robin what's that answer? Ok, can you tell Joey that answer? Ok Joey, tell me the answer". So I don't allow them to opt out, someone else will help them with the answer, and they'll have to give it back to me. They've bought into that. That's a big thing.
Sue: I think keeping the students engaged during the entire class period is really important. You have to have multiple things for them to do so that they keep busy throughout the entire time, because that I think is a key to class management. Is keeping them engaged all the time. If they're interested in something and working on something the entire time, then they are less likely to be a problem in the class. And breaking things up into smaller stuff.

Carly: Let me ask, how long can you hold their attention span? How long would you do an activity?

Robin: Depends on class, depends on the activity.

Carly: Do you have general guiding principles; is there a way you decide?

Robin: In terms of direct teaching, anything longer than 15 minutes is too much. If it's new material, that's about it. Then you try to do some group work, or even working at their table, if it’s a demo or an activity that goes with it. But to have them sitting there for 50 minutes taking notes?

Matt: When I was a kid, rarely once a blue moon, our teacher would show us a Mr. Wizard video or something for an hour. We’d sit there and watch it and hold our attention. I find with the kids even if you’re showing them a video clip that you think they can just sit there and watch a movie, no… 3-5 minute video clips. That’s their attention span. That’s it. Otherwise they’ll start talking, and then the whole class gets rowdy.

Paula: And that goes to directions too. You can’t give them 5 directions, you can’t say “First we want you to go to the table, then pick a partner…” No. You say the first thing we’re going to do is everyone find a table. And you’re going to sit down. And then you’re going to look up for the next directions. Ok, now we’re going to do this. And I think as you get to know the kids you can maybe do 1 or 2 direction, 3 or 4, but that’s something for non-teachers to realize. You can’t tell them to do 5 things.

Robin: And they’re not being belligerent. They really don’t remember the instructions.

Shawn: And it slows you down, and I think that sometimes as a teacher – because I want to get all my stuff in and I move around fast but – it slows you down, and you start feeling the guilt a little bit that “I’m not going to get to this”, but you know I’d rather be slow. I always tell them we’re turtles. The turtles always stop and think, make the right decisions, and they win the race in the end. I rather be slow and for them to understand, and hold the paper like this, horizontal, this is what horizontal means, and do this, this and this, rather than rush. Rushing does nothing. Doesn't help I mean. So, the slower the better, for me because my kids are a little slower than the others.

Matt: I think it's really tough too. You two, WPI students, school has been easy. You've worked hard, you've applied yourself… so when you start working with some of these kids who are not like you when you were a student or our students and you have to stop and put the brakes on, and be like "Whoa I have to bring it down to here". And it's not easy to do it at first, it's a shocker. It's definitely a shocker trying to give instructions, because you assume, at least I did, when I started teaching, that these students would be like I was when I was that age and that's not true.

Paula: But you're in a unique situation, because I've done programs like you're doing, in different parts of my career. And you are out of the norm, they're not in school. So they could have buy in, just to begin with. But to maintain the buy in, you have to use some of these tricks we're talking about.

Carly: They have a choice between us or basketball. Because over the years we've been gaining and I think we're actually winning against basketball.

Paula: That's great. And also you have this chance to light this spark for them, because we're stuck with frameworks and we have to have pace and you guys are young. You're a lot cooler. So you have that going for you to begin with. So high energy, positivity, no matter what.

Positivity is the most important thing, because a lot of kids come from very negative environments.

Carly: On that framework you mentioned, we actually have that question, because we know you have that those standards and that framework that you have to work to. Are there other things that you guys think like an extracurricular program like us that we're not bound by a framework, do you guys have suggestions for things that we should do, so that we're not repeating or boring them by doing too much school. Like are there things you wish they could do outside of school?

Paula: They need more engineering. And competitions is a good way. Like I used to run an engineering club and we just competed against each other.

Carly: Team competitions or small groups or individual?

Paula: Well depends on the project, depends on the kids, and if you want them to work in groups you have to lay out what that looks like. And how to treat each other. And think "this is what you're aiming for". You're aiming for people to talk to each other. When they talk to each other they speak to each other like this. And you might want to roleplay with the others that are your leaders. And this is what it looks like. And competitions really motivate kids that are very competitive in nature.

Matt: The other thing I can think of, and we used to have an after school program here and one year we had this woman come in she was a mathematician and she would build large structures out of business cards, like huge like half the size of this room. And what she was doing was coordinating all the Worcester public schools different schools for the kids to build these little cubes out of business cards. Anyways we had a program here and I was in charge of a group of kids. Every week what they loved was I would make these little name tags and each name tag was a job, and they would wear it in a lanyard around their neck. One was like, "you're the manager, you're the boss, you two are the assemblers, you're the counter", so every week they'd get a different job. And they loved it. "I wanna be the boss this week, or I want to do this". So that was really good in that kind of project based work because they knew exactly what they had to do and you didn't have to describe it.

Paula: And it was routine.

Matt: And it's routine, exactly, and they knew exactly what to do. But it was still fun. They were busy, and they had their hands busy and they were making something like you said, the engineering and the design stuff. They love that stuff, and I wish we could do more of that with them.

Robin: You see we're in this situation where our standards are 6^{th} through 8^{th}, and we're a 7^{th}-8^{th} school. And probably 75% of our kids have had science in elementary school. So we're trying to get 6^{th}-8^{th} and in fact K through 8^{th} in more than 2 years. And unfortunately we don't get to spend as much time doing engineering as we would like to. That's the bottom line.

Paula: As you know, innovation is the next thing. So for them to get sparked by that, is the most important thing you can do for society.

Carly: So when you guys are teaching lessons or doing hands-on activities, I know there are tests and quizzes, and scores and all that, but how do you guys judge if you're teaching it well, if the activity is successful, if the kids are really getting it. How do you tell that?

Robin: Well if the activity is authentic which means that it's a good as close to real world as you can get that is actually assessing what you taught, that you should solve the problem. Because kids, if you're doing some kind of a bit, the whole point is that they need to be able to know how to do something. So if they can actually do it in a lab setting, then you know you've done your job.

Argerius: And if they can make a connection, because most of them will do an activity and go "Oh that was cool", so this is a problem. So if they can make a connection, what is the bottom line? What did I train them to do? Why did I do this?

Paula: And have them write it down. But more specific, what does density mean? When we used this, how did it show? Giving them a chance to talk about it before they write it down, that's really helpful too.

Matt: When you're in the middle of the activity, when they're engaged, you can just tell. The other thing we go back to what you said, when you get connections two to three weeks later that's when you really know that it sunk in. "Oh well isn't that what we did when we did this, 2 weeks ago". "Yes!" And I love when that happens. But that doesn't seem like it happens that often.

Carly: So that's the general gist, I don't know if you guys have any other advice or point us in the right direction.

Matt: What were you thinking of doing, like, specifically?

Carly: So what they do is that they tend to come in, we tend do 2 activities, we do one activity then they have a dinner break, then we do a second activity. So, most of our activities are engineering. We have building activities like build a structure out of toothpicks and marshmallows, or spaghetti and marshmallows whatever supplies we have. We've done paper skyscrapers, "here's a bunch of paper, can you make the tallest tower you can without tape without glue, can you do that?" We have LEGO® Mindstorm robots, which aren't the greatest for building but use them. We teach the kids how to program so that they drag and drop visual programming language so there's a motion block and they can say move forward or turn left or turn right, and so we give them a maze they have to navigate the robot through the maze. Activities like that is what we're doing so far.

Matt: Tin foil, aluminum foil boats?

Carly: We've done duct tape boats in the past.

Matt: Hmm, not bad.

Carly: Actually I think we're doing that next week, because we have a special request for that one.

Matt: Egg drop or that could be a little scary?

Carly: It's on our list of potential activities, because our professor had some really good ideas. We showed videos during the dinner break, we showed them a video of the Mars rovers landing and the bouncing thing. So we're going to do the egg drop and come in: "The egg is your Mars Rover, you have to drop it on Mars".

Matt: The old, the first two… the new one they couldn't do, it's too heavy.

Paula: That's a good one, it's on PBS. November 14th on Nova, talking about Curiosity and how it's a ton and how to figure out how to land it. A really food 15 minutes of showing them the design process, and going through it, and prototyping and going back and redesigning and so… I just showed that in my class, might be a good one for you.

Robin: When that was landing they were holding their breath.

Paula: They went through this whole thing with the parachute. The parachute worked, and the second time they tried it it didn't work, and then they tried it 16 more times and it worked. And they had to get it not to work so they could fix it. It was a good video.

Matt: And your whole program is how many hours, 2 hours at night?

Carly: Yes it's 2 hours on Thursdays from 4 to 6 PM. With a dinner break in the middle, and they bring their own dinner.

Paula: I would Google "Science Thinking Challenges" and "Engineering Challenges". That's what I did when I was faced with your task.

Robin: I'm a life science person too.

Sue: Oh yeah that's really good, yeah.

Carly: So we have a list of 24 activities so far.

Robin: Do you tend to have the same kids?

Carly: Mostly, in past years the attendance has been really inconsistent. But actually this year, so far, we've had a better attendance. There are 16 kids total who come, and we usually get 12 of them who come each week. So we usually have 12 students there out of a total pool of 16 students.

Robin: Yes that's good, that they would stick with the program… that's a good sign.

Matt: Yeah. You have to have that good core group. Like I remember the year we did that project with business cards, I had like a group of 10 and they were great kids, and they were always there every week. Other years we did similar things, and if you get some kids that come sometimes, things start to unravel a little bit. That's good though, that's really good.

Sue: And interesting project that I saw recently, and I'm trying to remember where I saw it, I saw it online somewhere. A teacher had actually videotaped her students where they had a long-term project, where they worked on making edible cars. It was a car that was made out of food products. They had different kinds of food products available to them, and they had to think about what they could use for different parts of the car. The car had to be able to go down the ramp at a specific angle, and sometimes they had things that didn't roll enough or didn't stick enough like the wheels where they would have to go back and redesign and think about maybe using something else that was more secure. Maybe attaching their wheels on with frosting, or something like that to make it stick more. And that looked like a really fun and interesting project.

Matt: Reminds me of the Oscar Meyer Hot Dog Weiner mobile.

Sue: And you might be able to find that, if you go online, google "Edible Cars" or "Food and Cars"

Carly: Sounds fun, messy.

Sue: I think you might want to do that in a cafeteria.

Paula: Think ahead. What could go wrong. Think about what could go wrong and how it will break.

Matt: Is this going to be for the winter? Is this all indoors? Or do you get to go out with them and all? That could be fun too.

Carly: So far it has been all indoors, but there is some outdoor space if we need to do like the egg drop, we have the ability to go outside if we need to.

Paula: Well good luck ladies.

Everyone: Well if you need anything, let us know.

C. ELEMENTARY SCHOOL TEACHER INTERVIEW TRANSCRIPT

Bill: Well, I teach fifth grade at Grafton Street School, and the general academic standing of the students varies because you have different levels in the classroom. It is a very diverse neighborhood. Some students have had some type of home schooling before they came to school; some of them because of different situations have not had much of that, and that is what varies some of the levels. Also, some of them are English language learners. I have students in my classroom that just came from countries in Africa, other from Puerto Rico and they speak Spanish. The general academic standing in my classroom ranges. I have students that are A+ students and I have students that are not. So the range falls in the middle, from a C+ to a B-, somewhere in that 78 to 82% range. My class size is 25, but again, it varies depending on what group is coming through. I know that fourth grade had so many students that they had to make 3 fourth grades, while we only have two fifth grades. The fourth grade classes are smaller, but it is because there are three of them and they had to split them up whereas my class and the other fifth grade class I have 25 and the other fifth grade teacher (she) has 23. So that is the general size of the classrooms, and I have talked to a couple of schools in the city and they are also in the low 20 range.

Julieth: In Robokids, what we have is kids coming for a 2-hour session every Thursday when the kids come and we try to do activities with them, such as building things, related to STEM areas. We wanted to know how to deal, for example, with rowdy kids? How do you hold their attention? How much time you dedicate to activities for them not to get distracted? And if you fist lecture them and then work on specific activities?

Bill: I guess from my experience working with Friendly House kids as well as teaching them in public schools, you know, the best thing you can do with them since the beginning is try to build a rapport with them. You can't go in and just boss at them and tell them what to do because right away you're setting up a barrier with them. You wan to build a rapport with them that you are interested in them and you're interested in what they are interested in, but at the same time you still have to keep the…you know, have them see you as someone that is a teacher or as an authority figure at the school. And we were just talking about it yesterday in a meeting that it's a balance, you know it's a balance between building a friendship with the student but not letting them see you as a "buddy." You know what I mean?

Julieth: Yeah

Bill: So that's a way to prevent rowdy students in my room. I do have students that came in with wrong reputations…you know…of what they've done in the past. I haven't had any problems with certain students…being told: oh keep an eye on so and so, what out on so and so…you know they've kind of done things in the past, but those students that are in my room, I haven't had a problem with them. I built a rapport with them. You know, the general philosophy with any child is: they wanna know…they wanna be cared for, and they wanna be directed on what to do, otherwise the world is a big scary place to them…you know what I mean? I care about you, but there's gonna be discipline involved. It's a balance, it's a balance. So you know what you can do with the program maybe is when you first meet the group, try to just talk with them first, try to find out a little bit of what they're interested in, build a little bit of a rapport with them. If they talk to you a little bit before hand, they are less likely to act up during the program because they kinda like you, and they don't wanna act bad in front of you. If you do have a student that is rowdy, then at that time the first thing you wanna do is that you don't wanna call them out in front of everyone else because that sets the stage for them They are doing it because it's usually attention; I mean 9 times out of 10 is an attention-seeking behavior. So for you to call them out, they're gonna defend themselves naturally, if any was called out in front of a group specially your peers, you're gonna defend yourself. So you wanna get a chance to talk to them kind of a little bit close …you know, why is that behavior happening, what can you do to prevent it from happening. I have an advantage in a way over how you're doing the program because I see them in daily basis: 5 days a week, 6 hours a day, I am able to take time to build a relationship and I would ask them…can I speak to you in the hallway for a second please?...you know, and I say: Oh what's going on? We're having a good time. All the other students are raising the hands…You talk about all the positive things around them in hope that the follow them, instead of saying: don't be doing this! Don't be doing that! All that negative that you're throwing at them, they always hear that, they even outside of school, don't do this, don't do that, you're bad, you're doing this. That builds a barrier. So what you're trying to do is stay positive while in the conversation with. That's some of the things you can do with some of the rowdier students. Build a relationship with them I think is the best way to go.

Julieth: And for example, how do you manage to hold their attention and for how long? How much time do you dedicate to lecturing and then to doing the activities? Or do you do it the other way around?

Bill: The way I like to do it is that I present what they're going to be working on. Most recently we've been working on fractions. I present fractions to them. I talk to them; they stay engaged in the conversation. I ask them about the process and the steps that they are taking to for example adding fractions with different denominators. So what's the process that they use? You keep them engaged in the conversation. If you're back is to them, and you keep lecturing after a certain then half of them are asleep. I like to be entertaining in front of my room. I think that's a great way to keep their attention. Don't be afraid to be funny once in a while. Don't be afraid to say something a little shocking every once in a while because that shock humor or that shock attention perks them up…you know what I mean? One of the best advises that I got from a veteran teacher, someone who had taught for 33 years in the school department is that when you're in front of that classroom, you're on stage; you are a character. I am not [Teacher's Name]. I am [Teacher's Name] to my friends. But up there I am Mr. A, and that's who I am, and that's my character. Not that you're faking it, not that you're an actor, but that's how students see you.

Julieth: At that age specially…

Bill: At that age, yeah. If they see me outside of work…I saw a student at PetCo recently, and she was shocked! I was wearing regular clothe, I had my son with me, and she just couldn't believe that teacher's are human

Julieth: [laughs]

Bill: So, you know, go up there, give them something, you wanna be entertaining. No one wants to hear monotone lecturing. It puts anyone to sleep. So go up there, you are character. Whoever your character is at that time, that's the way they see you as. So perform it out. Keep their attention by being entertaining. There's nothing wrong with that.

Julieth: And what about competition? Do you put them to do some kind of competition during class? And if so, would it be in teams or individually? Does that motivate them?

Bill: A little of both. Again, I have 180 days of school, so I use many different methods along the way. Competition I feel is great. Competition is motivation. They get fired up, they want to compete against something. The example is when they go to gym class and after competing against each other and they come back in the room, they're still arguing about a play that happened in the gym. So some more than others, they have that competitive fire in them. You harness that and you bring in to games in the classroom. The best way to do it is to keep a fair competition. What we use in the school department is differentiated instruction. Different kids in my classroom have different levels. I am not going to put someone who is at a very very high level against someone who is at a very very low level in a Math competition because it's embarrassing for the student. So I differentiate instruction by keeping them equal. Equal people go against equal people in that room. If you're in the higher level, you're going against the higher level. And there are different things you can do: I have three boys that are at that very high level in Math, an above level Math for their age. I also have three girls that are at an above level Math. And they like to get a little competitive with each other. The old fashion boys versus girls. Just for the record, the girls have been dominating this year. You keep it fun, you let them know that it's competitive and that there might be a small prize at the end, but it's all in good nature, it's all in good fun. Never let it get carried away.

Julieth: Is it usually individual or in teams? And if you do it in teams, then how do you make sure each member of the team gets their part?

Bill: One of the things I use when we play a certain game, which is kind of like a jeopardy, is that we have points up on the board, the cards are flipped over, you gotta go take one off the board and that's the question. The way I differentiate the instructions in my room is that I walk around with something as simple as playing-cards. I separate them before hand and there are 2s in the pile, 3s in the pile, and 4s in the pile. So they don't know I am differentiating instructions at that point. I walk around and say: I'm gonna give you a card faced down. No one turn your card over. The rules of the game are: the 2s can go against the 3s, the 3s can go against the 4s or the 2s. You can only go one up or one down to compete. And that keeps them at a certain level. And I say ok on this team (there's a whole team versus another one on the other side of the classroom) who has the 4s. A couple of people put their hands up. I call up one of those students and I say ok who on this other side has 3s, 4s or 5s. And they I ask the student to pick someone they he would like to compete against on the other team. Usually is one of their friends that they are trying to get the better of. But at that time the competition is fairly fair and they are within a range of each other for Math. The queens, the kings and some of the face cards that go out, they can only go against each other in that group of queens, kings and faced cards. And those will be the harder Math problems that I'll pull off the board. You have to get creative with differentiated instructions, and they don't know the difference. They go about their business, they look at their cards and don't want anyone to see their cards. It doesn't hurt feeling along the way. Again is a balance.

Julieth: When you teach a class or do some kind of competition, how do you judge the learning outcomes of the students and make sure that they actually learned something and they can relate it to something else?

Bill: Well, going back to what we've done over the past two weeks, not only we've been doing fractions but also percentages. So I said, who's going out holiday shopping? And a lot of hands went up in the room. So I said, you know since it's the holiday season, all you see is percentages on sales: 20% off, 30% off, 40 % off. So you incorporate it into everyday-life, other than just today. So I said, if you go to the mall this weekend with your parents for shopping, I want you to (because they have now learned the skills over the past two weeks) look at a t-shirt and see that is 20% off, and I want you to calculate what you think it is. How do I observe them in the classroom? I present, I ask if we can get any questions out of the way, maybe a worksheet will go out to them, I do the first 2 or 3 problems up on the board to kick a start and get the going, and at that time I circulate around the room. If you have a question you put your hand up. I sit right next to you, I talk to you about it. The ones who got it, I let them go, go for it, do your worksheet. That kinda gives me time. Instead of addressing 25 issues, I might only get 2 or 3 hands up at a time and say ok I'm gonna go with one, then I'm gonna come to you, and then to you. And it gives me a chance to sit individually with them and that's when they get one on one attention. So for the students who don't need the one on one, as I walk around the room, I observe their worksheet. I walk by, they know I'm checking on them, I just check their paper, spot-check a couple of problems. If they're doing it right, I keep going. And if they're not I say why did you use this denominator instead of using a different one, and I try to find out what's going on so we can fix it a little bit.

Julieth: And now referring to the last questions, what would you particularly like to see your students do in STEM-based extracurricular activities? More engineering, more technology…?

Bill: Oh wow, that's an easy answer I think. Technology over the last 25 years has advanced faster than it did in the first 100 years before that and computers have been a large part of that. So to introduce them to how things work, why things work a certain way, the whole engineering process of it, the whole technology aspect of the world. That's where the world has moved to. And the world is moving in that direction. So the importance of it is that if you're gonna get a job, if you're going to stay current, if you want to create or be innovative or use something, you need to be on board, you need to be on board with technology and where it is moving. So introducing them at a young age is fantastic. I'm amazed that students who are only 8 and 9 years old can get around that computer and they own it, they know it. And I think that's fantastic because I remember when we got a computer in the house and I was like "what is this?" At was at that age when computers where just coming out to each household and there wasn't even Internet yet, it was just the computer so far. I remember when I was a kid going on Paintbrush and all those things you could create on it, and I just thought that was fantastic. And I look at then, which wasn't that long ago, and I look at now with the Internet and everything has just advanced so fast. Their age group, your age group, is the age of information. With the click of a button, with the click of a phone, with the click of an app, you can obtain any information. So what you're doing with the students is that you're making them current. You're helping to prepare them in the technology aspect, in the engineering aspect for what they're going to dive into not too long from where they are. My students are 10, when they're 20, they'll be in college and they're gonna have to be involved. So you're not talking about many years away, you're talking about a quick decade, and there they go. I think the program is fantastic. I read it on the computer, and you've explained it a little bit, and I'm so glad that you're working with the Friendly House, I worked with the Friendly House, I mean I went to the Friendly House since I was 8 years old and I haven't left. I'm so happy that you guys are doing that program, I think it's fantastic.

Julieth: Thank you.

Carly: Actually, going back to the computers thing. Do they do a lot of computer stuff in school?

Bill: You know for the city wide, we know we don't have a ton of money in the city, let's rule that out there. So for them to buy us computers for everyone in the school and to get the most up-to-date, and technology moves so fast that our computers are, in my classroom I have 5 of them for 25 students, the boxed one, they are not even the flat screen ones. So you could imagine that these are at least 10 years old. I mean technology moves so fast that the city can't come up with the money to produce flat-screen, up-to-date computers for every student in the school department. It's just too much to ask them to do. They have computer labs; our computer lab, through grants and through I believe the DELL Corporation, that they have been able to create computer rooms and stuff like that. It's one of those things, some of them get exposure at home, some of them, in our area, can't afford a computer for the house. So some are exposed and some are not. In school, at times they're exposed and other times they're not. It's so diverse, and it's so different depending on what house you live in, what school you go to. You know some of the schools have up-to-date, modern rooms, and you could be jealous of them, but at the same time you have to be reasonable and say well they did this now and then they'll work on this other school and then they'll work on this other one and so on. They're doing what they can with the small finances they have. Are you guys involving them through the program with computers?

Julieth: We have them sometimes work on laptops doing some programming.

Carly: Yeah, we teach them to program some LEGO robots with the drag and drop…it's a pictorial programming language. And we've also done SCRATCH, which is another drag-and-drop programming language. And we have access to computer labs, so that's something for the kids who aren't getting a lot of computer exposure at school. That's something that we could design activities for.

Bill: That would be fantastic because 1- they enjoy it, they wanna be on the computer, that's their whole generation, their whole age is one the computer, they're just fascinated with it and 2- with the right program, with the right people showing them what to do, instead of just going on YouTube watching ridiculous videos, you can show them that the computer, I tell them all the time, the computer is a fantastic resource to anything you wanna know, anything that you really wanna do. You can find, if you know where to search, if you know how to create and by you exposing them to that, that's gonna leap them, that's gonna jump them forward because watching people who fall off skateboards on YouTube all day isn't the educational purpose of the computer; it's an entertainment for them, but let's use it more as an educational resource because they haven't grabbed that concept yet. So I think that by implementing something in a computer, this computer would be a huge step for them, and that would be a huge step for you guys too.

Carly: Ok, I think that's it, unless you have any more questions for him Julie.

Julieth: No, I'm fine. I don't have any more questions. Thank you so much!

Carly: Thank you so much!

Bill: Thank you so much for inviting me. I'm glad to help with this.

APPENDIX 4

A. DETAILED ACTIVITY LIST

1. HIGH PRIORITY

- **Programming LEGO Bots**
  STEM areas: Technology, Engineering
  Relation to Robotics: it is a robot!

- **Electrical Circuits – squishy playdough**
  STEM areas: Science, Engineering
  Relation to Robotics: circuits are how sensors communicate to the brain of the robot, and how the brain communicates to the "limbs".

- **Human Blindfold Sensors**
  STEM areas: Technology, Engineering
  Relation to Robotics: sensors are like the robot's 5 senses. They are how it gathers information about its environment.

- **Linkages (popsicle sticks with brad pins)**
  STEM areas: Engineering
  Relation to Robotics: linkages are used for robot arms, etc. (video example).

- **Million Dollar Project**
  STEM areas: Mathematics
  Relation to Robotics: programming is math, circuits are designed with math, torque is calculated with math – robots are made of math!

- **Egg Drop**
  STEM areas: Science
  Relation to Robotics: By learning how to protect the eggs, participants will understand how the design of the mars rovers guarantees their protection.

- **Cup Stacking with Math**
  STEM areas: Math
  Relation to Robotics: programming is math, circuits are designed with math, torque is calculated with math – robots are made of math!

- **Roller Coasters for Marbles**
  STEM areas: Math, Science, Engineering
  Relation to Robotics: Robotics involves building things appropriately, which in turn involves Math and Science. In this activity, participants will learn what they need to keep in mind when building things, like robots, so they will not break or perform inappropriately.

2. LOW PRIORITY

- **Torque Mobiles / Simple Machines**
  STEM areas: Science, Engineering
  Relation to Robotics: torque is applicable to arms, wheels, lifting loads, etc., Robotics utilizes the basic principles of Simple Machines

- **Bubble Sort Floor Map**
  STEM areas: Technology
  Relation to Robotics: an intro to programming algorithms – robots that need to collect data, and then organize it to store & use it

- **Counting in Binary**
  STEM areas: Technology
  Relation to Robotics: intro to how computers think and how programming works.

- **Peanut Butter Jelly Time**
  STEM areas: Engineering, Technology
  Relation to Robotics: an intro to programming. Robots will only do EXACTLY as the program tells them – it cannot infer what you "meant"

- **Spaghetti and Marshmallow**
  STEM areas: Science, Engineering
  Relation to Robotics: robots are meaningless if they are not durable and stay together. Building can be complicated and should be planned in advance.

- **Paper Skyscrapers**
  STEM areas: Science, Engineering
  Relation to Robotics: there are often limits on what supplies you can use, whether it's to save weight, or if a robot has to stand up to high temperatures, or vacuum, or water. You have to be creative despite the restriction on materials

- **Paper Airplane Iterations**
  STEM areas: Engineering
  Relation to Robotics: robots have to be improved over and over.

- **OM brainstorming**
  STEM areas: Engineering
  Relation to Robotics: how do you plan your LEGO robot to solve a challenge? Brainstorming is about coming up with ideas of how to complete some challenge. For example, if I need to make a robot to climb over a pile of rocks.

- **Mad Minutes**
  STEM areas: Mathematics
  Relation to Robotics: programming is math, circuits are designed with math, torque is calculated with math – robots are made of math!

- **Graphing**
  STEM areas: Mathematics, (Technology)
  Relation to Robotics: graphs help us make sense of the math by putting it in pretty pictures. It allows us to model/simulate a robot design *before* we build it so we can find weaknesses ahead of time.

- **Gear Ratios**
  STEM areas: Engineering
  Relation to Robotics: gears are used to help wheels go fast or push strongly, or help an arm raise a heavy load or raise a small load quickly.

- **Robot Design**
  STEM areas: Engineering
  Relation to Robotics: how do you make sure your robot will be able to perform all the tasks you need it to do? Brainstorming is about coming up with ideas of how to complete some challenge. For example, if I need to make a robot to climb over a pile of rocks.

- **The Robot Research Project**
  STEM areas: Engineering
  Relation to Robotics: participants will be asked to do research about how was their (real life already existing) assigned robot created, the main tasks it performs and how its design allows it to perform them. By completing this research participants will gain a better understanding of how robots are designed and built.

- **Building Rockets**
  STEM areas: Engineering
  Relation to Robotics: Robotics involves building things appropriately. In this activity, participants will learn what they need to keep in mind when building things, like robots, so they will not break or perform inappropriately.

- **Laser**
  STEM areas: Science
  Relation to Robotics: Robots use lasers and other types of sensors. Participants will learn how lasers work and why some robots use them.

- **Box Cars with Weights**
  STEM: Science, Engineering
  Relation to Robotics: There are two versions of this activity. The first one consists of making participants analyze the relation between weight and distance traveled by the cars. The second one consists of making participants actually build the cars and put weights on them. In this version of the activity, participants will have to analyze how to properly build the cars so they can travel properly and then analyze the relation between weight and distance traveled by the cars.

- **Duct Tape Boats**
  STEM: Science, Engineering
  Relation to Robotics: Distributing load – either robot on surface or load on robot. How can you best support that load?

B. VIDEO LIST

Swimming Humanoid Robot: http://spectrum.ieee.org/automaton/robotics/robotics-hardware/video-friday-humanoid-swimming-last-moment-robot-r2d2-sells-you-prius

DARPA ARM, NASA's Robonaut2, Willow Garage's PR2, Intuitive Surgical Da Vinci, and Scout from ReconRobotics:
http://spectrum.ieee.org/automaton/robotics/industrial-robots/icra-2012-video-montage

Drexel's HUBO humanoid pitching:
http://spectrum.ieee.org/automaton/robotics/diy/video-friday-talking-vacuums-robotic-buttocks-and-how-not-to-fly-a-spacecraft
PR2 robot doing the Macarena: http://spectrum.ieee.org/automaton/robotics/diy/video-friday-talking-vacuums-robotic-buttocks-and-how-not-to-fly-a-spacecraft

Cocorobo (vacuum cleaning robot):
http://spectrum.ieee.org/automaton/robotics/diy/video-friday-talking-vacuums-robotic-buttocks-and-how-not-to-fly-a-spacecraft

TurtleBot Easter:
http://spectrum.ieee.org/automaton/robotics/diy/video-friday-happy-easter

Morphex Spherical Transforming Hexapod Robot:
http://spectrum.ieee.org/automaton/robotics/diy/video-friday-happy-easter

Mutant Ninja Turtle Robot: http://spectrum.ieee.org/automaton/robotics/diy/video-friday-happy-easter

Chinese New Year 2012 Dancing Robots:
http://spectrum.ieee.org/automaton/robotics/diy/video-friday-dancing-robots-sumo-robots-war-robots-more

Robot Christmas:
http://spectrum.ieee.org/automaton/robotics/artificial-intelligence/generalized-nondenominational-holiday-greetings-from-automaton

PETMAN:
http://spectrum.ieee.org/automaton/robotics/humanoids/stunning-video-of-boston-dynamics-petman-humanoid

Willow Garage Robots:
http://spectrum.ieee.org/automaton/robotics/diy/iros-2011-expo-gallery

A Robot that Balances on a Ball: http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

PR2 folding towels:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

HRP-4 Humanoid:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Flying robot:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Geminoid F (female humanoid):
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

iRobot 710 warrior:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Honda U3-X personal mobility device:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Engineers turn robot arm into Ferrari simulator:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Humanoid called Surena (walks, stands on one foot, and performs a little dance):
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Humanoid Robot ASIMO:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Skinny alien-looking robot:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Athlete robot:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

Advanced Musculoskeletal Humanoid Robot Kojiro:
http://spectrum.ieee.org/automaton/robotics/robotics-software/top-20-robot-videos-of-2010

StarlETH LittleDog:
http://spectrum.ieee.org/automaton/robotics/robotics-hardware/video-friday-and-laser-snakes

New Lego Mindstorms EV3 Robotic Kits (snake robot):
http://spectrum.ieee.org/automaton/robotics/home-robots/video-friday-ces-robots-first-competition-power-loader

Window cleaning robot:
http://spectrum.ieee.org/automaton/robotics/home-robots/video-friday-ces-robots-first-competition-power-loader

Parrot AR Drone:
http://spectrum.ieee.org/automaton/robotics/home-robots/video-friday-ces-robots-first-competition-power-loader

Titanoboa, a giant snake robot:
http://spectrum.ieee.org/automaton/robotics/home-robots/video-friday-ces-robots-first-competition-power-loader

APPENDIX 5

A. DETAILED STUDENT ATTENDANCE

Student Attendance								
Name	**Linkages**	**Kit Explore**	**Shapes**	**Line**	**Bump / Cups**	**3 Maze**	**Million Dollar**	**Gears / Racing**
Student 1	A	P	A	A	A	A	A	A
Student 2	P	P	P	P	P	A	P	P
Student 3	P	A	P	A	P	P	A	A
Student 4	P	A	P	P	P	P	A	P
Student 5	A	A	A	P	A	A	P	P
Student 6	P	P	A	P	P	P	P	P
Student 8	P	P	A	A	A	A	P	A
Student 9	P	P	P	P	P	P	P	P
Student 10	P	P	A	A	A	A	A	A
Student 11	P	P	P	P	P	P	P	A
Student 12	P	A	A	A	A	A	A	A
Student 15	A	P	P	P	P	P	P	P
Student 16	P	P	P	P	P	A	A	A
Student 17	N/A	N/A	P	P	P	P	P	A
Student 18	N/A	N/A	P	P	P	A	P	A
Student 19	N/A	N/A	N/A	P	P	P	A	A

Legend and Important Notes:

A = Absent; P = Present; N/A = Not Applicable

***Students **7**, **13** and **14** were affiliated to the program before this research study was initiated, but they never attended any of the sessions included in this study.
*** Students **17** and **18** were new additions to the program since 1/17/13 (**Shapes**)
*** Student **19** was a new addition to the program since 1/24/13 (**Line**)

B. GENERALIZED STUDENT ATTENDANCE

Important Note:

While there were 19 students affiliated with the program, the maximum amount of students per session was strictly limited to 15 due to Worcester Friendly House transportation regulations

Date	# Present	# Absent
Linkages	10	5
Kit Explore	9	6
Shapes	9	6
Line	11	4
Bump / Cups	11	4
3 Maze	8	7
Million Dollar	9	6
Gears / Racing	6	9

C. DETAILED MENTOR ATTENDANCE

Mentor Attendance								
Name	**Linkages**	**Kit Explore**	**Shapes**	**Line**	**Bump / Cups**	**3 Maze**	**Million Dollar**	**Gears / Racing**
Mentor 1	P	P	P	P	P	P	P	P
Mentor 2	P	P	P	P	P	P	P	P
Mentor 3	P	P	P	P	P	A	A	A
Mentor 4	P	A	P	P	P	A	A	P
Mentor 5	A	P	A	P	P	A	A	P
Mentor 6	N/A	N/A	P	P	A	P	A	P
Mentor 7	N/A	N/A	P	A	P	A	A	A
Mentor 8	N/A	N/A	N/A	P	P	A	A	A
Mentor 9	N/A	N/A	N/A	N/A	P	P	A	P
Mentor 10	N/A	N/A	N/A	N/A	N/A	N/A	P	P

Legend and Important Notes:

A = Absent; P = Present; N/A = Not Applicable

*** Mentors **6** and **7** were new additions to the program since 1/17/13 (**Shapes**)
*** Mentor **8** was a new addition to the program since 1/24/13 (**Line**)
*** Mentor **9** was a new addition to the program since 1/31/13 (**Bump / Cups**)
*** Mentor **10** was a new addition to the program since 3/14/13 (**Million Dollar**)

D. GENERALIZED MENTOR ATTENDANCE

Date	# Present	# Absent
Linkages	4	1
Kit Explore	4	1
Shapes	6	1
Line	7	1
Bump / Cups	8	1
3 Maze	4	5
Million Dollar	3	7
Gears / Racing	7	3

APPENDIX 6

A. STUDENTS WEEKLY FEEDBACK SURVEY – PRODUCING ACTIVITY

Name: ____

Activity: ____

- Did you enjoy the activity?

Very much Just a little Not at all

- Why?

____

____

- Have you done a similar activity before?

Yes Not sure No

- How difficult was the activity?

Very Hard Sort of hard Neither hard or easy Sort of easy Very easy

- Would you change the difficulty of the activity?

Yes, make it harder No, leave it the same Yes, make it easier

- Did you finish the activity in the time given?

Yes, with extra Yes, barely No, but close No, and not close

- Which area did the activity relate to?

Science Technology Engineering Math Computer Science

- Would you like to learn more about this area?

Yes, lots more Yes, a little bit I don’t care Not really

B. STUDENTS WEEKLY FEEDBACK SURVEY – NON-PRODUCING ACTIVITY

Name: ____

Activity: ____

- Did you enjoy the activity?

Very much   Just a little   Not at all

- Why?

____

____

- Have you done a similar activity before?

Yes   Not sure   No

- Which area did the activity relate to?

Science   Technology   Engineering   Math   Computer Science

- How?

____

____

- Give a real-life example where this could be applied.

____

____

- Would you like to learn more about this area?

Yes, lots more   Yes, a little bit   I don't care   Not really

C. STUDENT WEEKLY FEEDBACK RESULTS

1. LINKAGES (11/29/12)

Linkages (11/29/12)							
What area did the activity relate to?							
Science	S9	S15					
Technology	S4	S8	S9				
Engineering	S3	S4	S6	S8	S9	S11	S15
Math	S2						
Computer Science							
Would you like to learn more about this area?							
Yes, lots	S3	S8					
Yes, a little	S4	S6	S9	S11	S15		
I don't care							
Not really	S2						

Why did you enjoy or not enjoy the activity?

S2: Well I didn't really like this activity because I was hopeing we could do something with duck tape and bits and bolts.

S3: I kinda liked the activity because it looked fun at first but then me and my partner got frustrated

S4: Because sometimes there are some thing that interest me a little

S6: because I didn't know how to do it and it was confusing

S8: Because it was hard! Tools we needed more holes in the board

S9: I thought the activity was really cool and awesome

S11: I thought it was a little hard and that we did to many steps all at once. It was also kind of aggravating that we kept messing up.

S15: Because it wasn't that much fun

2. KIT EXPLORATION/BUILD BASEBOT (12/06/12)

Kit Exploration / Build Basebot (12/6/12)							
Did you enjoy the activity?							
Very Much	S2	S8	S11				
Just a little	S6						
Not at all							
Have you done a similar activity before?							
Yes	S2	S6	S8				
Not Sure							
No	S11						
How difficult was the activity?							
Very Hard							
Sort of Hard	S6						
Neither hard or easy	S11						
Sort of Easy							
Very Easy	S2	S8					
Would you change the difficulty?							
Yes, harder	S8						
No, the same	S2						
Yes, easier	S6	S11					
Did you finish in time?							
Yes, with extra	S2	S6	S8				
Yes, barely	S11						
No, but close							
No, not close							
What area did the activity relate to?							
Science	S8						
Technology	S8	S11					
Engineering	S2	S6	S8				
Math	S8						
Computer Science	S8						
Would you like to learn more about this area?							
Yes, lots	S8						
Yes, a little	S11						
I don't care	S2	S6					
Not really							

Why did you enjoy or not enjoy the activity?

S2: cause robot danced.

S6: Because I didn't know what to do and people kept on hogging the directions

S8: Just because

S11: We got to make our own robot for the first time

3. PROGRAMMING SHAPES (01/17/13)

Programing Shapes (01/17/13)								
Did you enjoy the activity?								
Very Much	S2	S3	S4	S9	S11	S16	S17	S18
Just a little	S15							
Not at all								
Have you done a similar activity before?								
Yes	S2	S11						
Not Sure	S9	S15	S16	S17				
No	S4	S18						
N/A	S3							
How difficult was the activity?								
Very Hard								
Sort of Hard	S2	S4	S9	S16				
Neither hard or easy	S3	S15						
Sort of Easy	S11	S18						
Very Easy	S17							
Would you change the difficulty?								
Yes, harder	S16							
No, the same	S2	S3	S4	S9	S11	S15	S18	
Yes, easier	S17							
Did you finish in time?								
Yes, with extra	S4	S18						
Yes, barely	S2	S3	S9	S11	S15	S16	S17	
No, but close								
No, not close								
What area did the activity relate to?								
Science	S9							
Technology	S9							
Engineering	S2	S3	S9	S15	S18			
Math	S2	S9	S18					
Computer Science	S2	S4	S9	S11	S16			
Would you like to learn more about this area?								
Yes, lots	S9	S11	S18					
Yes, a little	S2	S3	S4	S15	S16	S17		
I don't care								
Not really								

Why did you enjoy or not enjoy the activity?

S2: Because it is something I haven't done before

S3: I liked it a lot because I was involved a lot during the activity.

S4: Robots and legos

S9: I enjoyed this activity because it is a hands on project.

S11: We got to learn how to program robots and they were already built.

S15: Because we had to program the robot and we have to make shapes

S16: Because we get to make the robots draw some shape

S17: because it's fun and we get to go more then once and we get to play with the robots then after we get candy but the winner gets more candy then other people

S18: Because I learned you need to connect wires from the computer to the robot and what to connect to em

4. HUMAN SENSORS (01/24/13)

Human Sensors (01/24/13)								
Did you enjoy the activity?								
Very Much	S9	S11	S17	S19				
Just a little	S2	S6	S16					
Not at all	S15							
Have you done a similar activity before?								
Yes	S2							
Not Sure	S11	S15	S16	S17	S19			
No	S6	S9						
How difficult was the activity?								
Very Hard								
Sort of Hard	S9							
Neither hard or easy	S16	S19						
Sort of Easy								
Very Easy	S2	S6	S11	S15	S17			
Would you change the difficulty?								
Yes, harder	S2	S11	S15	S17				
No, the same	S6	S9	S16	S19				
Yes, easier								
Did you finish in time?								
Yes, with extra	S2	S6	S9	S15				
Yes, barely	S11	S16	S17	S19				
No, but close								
No, not close								
What area did the activity relate to?								
Science	S9							
Technology	S9							
Engineering	S9	S11	S15	S16	S17			
Math	S9							
Computer Science	S2	S6	S9	S19				
Would you like to learn more about this area?								
Yes, lots	S11	S15						
Yes, a little	S6	S9	S16	S17				
I don't care								
Not really	S2	S19						

Why did you enjoy or not enjoy the activity?

S2: Because its not fun

S6: I don't know

S9: I enjoyed it because it was a hands-on activity

S11: We were the robots and we took turns controlling eachother. We got to make mazes out of tables too.

S15: Because it was not fun at all

S16: Because it was a little boring and a little fun

S17: Because it was fun and I get to learn about robots.

S19: Because it is very very fun

5. LINE FOLLOWING (01/24/13)

Line Following (01/24/13)								
Did you enjoy the activity?								
Very Much	S9	S15	S16	S17	S18			
Just a little	S2	S6	S11					
Not at all	S19							
Have you done a similar activity before?								
Yes	S11	S15						
Not Sure	S6	S16	S18					
No	S19							
How difficult was the activity?								
Very Hard	S11	S15						
Sort of Hard	S6	S9	S18					
Neither hard or easy	S16							
Sort of Easy	S2							
Very Easy	S18	S19						
Would you change the difficulty?								
Yes, harder	S15	S17						
No, the same	S9	S16						
Yes, easier	S2	S11	S18	S19				
N/A	S6							
Did you finish in time?								
Yes, with extra	S2	S6	S9	S15				
Yes, barely	S11	S16	S17	S20				
No, but close								
No, not close								
What area did the activity relate to?								
Science	S6	S9						
Technology	S9	S15	S18					
Engineering	S6	S9	S11	S17				
Math	S9							
Computer Science	S2	S6	S9	S16	S19			
Would you like to learn more about this area?								
Yes, lots	S15	S17	S18					
Yes, a little	S9	S11	S16					
I don't care	S2	S19						
Not really	S6							

Why did you enjoy or not enjoy the activity?

S2: I don't. Boring. Because CC is not here.

S6: Cuz it was kina hard at first then it got easier

S9: Because it was fun

S11: It was kind of hard and to complicated

S15: Because it was fun

S16: Because we get to use the robots

S17: Because we got to control the roots to do what ever we want it to do

S18: I programmed a robot to sence a line and look for one.

S19: Because it is not fun

6. BUMP SENSORS (01/31/13)

Bump Sensors (01/31/13)								
Did you enjoy the activity?								
Very Much	S3	S15	S18	S19				
Just a little	S9	S16	S17					
Not at all	S6	S11						
Have you done a similar activity before?								
Yes	S11	S15						
Not Sure	S6	S16	S18					
No	S3	S9	S18	S19				
How difficult was the activity?								
Very Hard	S18							
Sort of Hard	S6	S9	S11	S16	S17	S19		
Neither hard or easy	S3	S15						
Sort of Easy								
Very Easy								
Would you change the difficulty?								
Yes, harder	S15	S17						
No, the same	S16	S18	S19					
Yes, easier	S3	S6	S9	S11				
N/A								
Did you finish in time?								
Yes, with extra								
Yes, barely	S16	S18						
No, but close	S9	S15	S17	S19				
No, not close	S3	S6	S11					
What area did the activity relate to?								
Science	S6	S9						
Technology	S6	S9						
Engineering	S6	S9	S11	S15	S17	S18		
Math	S9							
Computer Science	S6	S9	S16	S19				
Would you like to learn more about this area?								
Yes, lots	S18							
Yes, a little	S3	S9	S16	S17				
I don't care	S15	S19						
Not really	S6	S11						

Why did you enjoy or not enjoy the activity?
S3: I learned new things like radius and othrer things
S6: Cuse it was hard
S9: Because it was hand's on project
S11: It was hard and kind of boring
S15: It was fun
S16: Because the robot's need's to go throught the maze
S18: Ive got to program something
S19: It was fun

7. NUMBERED CUPS (01/31/13)

Numbered Cups (01/31/13)

Did you enjoy the activity?								
Very Much	S2	S3	S9	S11	S15	S16	S17	
Just a little	S6							
Not at all	S18	S19						

Why?

S2: Because it was fun
S3: I liked the activity because we worked as a team and not by ourselves
S6: Cuz it got boring then it got entristing
S9: Because it was fun
S11: We did something that im youst to doing
S15: It was fun
S16: Because we get to stack cups
S17: Because what we were doing was fun and every time we get some thing right we get candy
S18: I kept losing to a girl
S19: Because I did NOT WIN

Have you done a similar activity before?								
Yes	S2	S6	S9	S11	S15	S17	S19	
Not Sure	S16							
No	S3	S18						
What area did the activity relate to?								
Science	S2	S6						
Technology								
Engineering	S9	S15	S17	S18				
Math	S3	S11	S15	S16	S18			
Computer Science								
I don't know	S19							

How?

S2: Because of gravity
S3: We multiplied added and looked for odd and even numbers
S6: U had to balance a lot
S9: Because you need to build the cup pyramid
S11: We had to add up numbers on cups that we were stacking
S15: I to bilct
S16: Because we had to multiple
S17: n/a
S18: I was adding multiple of three
S19: n/a

Give a real-life example where this could be applied
S2: fast stacking S3: This activity could be applied at school to make math fun S6: At home S9: Shopping S11: A stacking competition S15: I to bilct S16: Were we use numbers S17: n/a S18: Building stuff S19: In a compatising

Would you like to learn more about this area?								
Yes, lots	S3	S15	S16	S17				
Yes, a little	S9	S18						
I don't care	S2	S11						
Not really	S6							
N/A	S19							

8. THREE SENSOR MAZE (02/07/13)

3 Sensor Maze (02/7/13)								
Did you enjoy the activity?								
Very Much	S3	S4	S15	S17	S19			
Just a little	S6	S9	S11					
Not at all								
Have you done a similar activity before?								
Yes	S6	S11	S15	S17				
Not Sure								
No	S3	S4	S9	S19				
How difficult was the activity?								
Very Hard	S9	S15						
Sort of Hard	S4	S6	S17					
Neither hard or easy	S11							
Sort of Easy	S3							
Very Easy	S6	S19						
Would you change the difficulty?								
Yes, harder	S15	S17						
No, the same	S3	S4	S11	S19				
Yes, easier	S6	S9						
Did you finish in time?								
Yes, with extra								
Yes, barely	S3	S15	S19					
No, but close	S4	S11	S17					
No, not close	S6	S9						
What area did the activity relate to?								
Science	S6							
Technology	S4	S6	S9					
Engineering	S3	S6	S9	S11	S15	S17		
Math								
Computer Science	S6	S9	S19					
Would you like to learn more about this area?								
Yes, lots	S4	S17						
Yes, a little	S3	S9	S11	S15				
I don't care	S6	S19						
Not really								

Why did you enjoy or not enjoy the activity?

S3: It was F.U.N!

S4: Maze, lego robots, and excitement

S6: cuz it was hard for most of the part and it was kinda boring

S9: Because it was a hands on activity

S11: I liked it because it was easier than last time.

S15: It was fun

S17: because we get to make the robot do path and it's fun to make it talk

S19: I do like it. I don’t love u. Mean paper.

9. MILLION DOLLAR PROJECT (03/14/13)

Million Dollar Project (03/14/13)									
Did you enjoy the activity?									
Very Much	S2	S5	S6	S9	S11	S15	S17	S18	
Just a little	S8								
Not at all									
Have you done a similar activity before?									
Yes									
Not Sure	S2	S15							
No	S5	S6	S8	S9	S11	S17	S18		
How difficult was the activity?									
Very Hard	S17								
Sort of Hard	S8	S9							
Neither hard or easy	S5	S11							
Sort of Easy	S2	S6	S18						
Very Easy	S15								
Would you change the difficulty?									
Yes, harder	S15								
No, the same	S2	S5	S6	S9	S11	S17	S18		
Yes, easier	S8								
Did you finish in time?									
Yes, with extra	S2	S8	S9	S18					
Yes, barely	S5	S6	S11	S15	S17				
No, but close									
No, not close									
What area did the activity relate to?									
Science									
Technology	S9								
Engineering	S9								
Math	S2	S5	S6	S8	S9	S11	S15	S17	S18
Computer Science									
Would you like to learn more about this area?									
Yes, lots	S2	S5	S9	S11	S15	S18			
Yes, a little	S6	S8	S17						
I don't care									
Not really									

Why did you enjoy or not enjoy the activity?
S2: Lost of fun S5: I enjoyed it because you get to have fun, you get to hang out with friends and be yourself S6: Because it was fun S8: It was very hard S9: I thought it was really cool and I thought it was neat S11: Because it had a lot of organizing math and dividing S15: Because I did nothing S17: I had a computer bussines S18: Because I had a computer store
Suggestions:
S9: I think you should do restaurants, and more stores. Thank you for considering my ideas.

10. INTRO TO GEARS (03/21/13)

Intro to Gears (03/21/13)								
Did you enjoy the activity?								
Very Much	S2	S4						
Just a little	S5	S6	S9					
Not at all	S15							
Have you done a similar activity before?								
Yes	S2	S9						
Not Sure	S15							
No	S4	S5	S6					
How difficult was the activity?								
Very Hard								
Sort of Hard	S2	S6						
Neither hard or easy	S4							
Sort of Easy								
Very Easy	S3	S9	S15					
Would you change the difficulty?								
Yes, harder	S5	S9	S15					
No, the same	S4							
Yes, easier	S2	S6						
Did you finish in time?								
Yes, with extra	S2	S4	S9					
Yes, barely	S5	S15						
No, but close	S6							
No, not close								
What area did the activity relate to?								
Science	S9	S15						
Technology	S4	S9						
Engineering	S2	S4	S9					
Math	S4	S5	S6	S9				
Computer Science								
Would you like to learn more about this area?								
Yes, lots	S4							
Yes, a little	S9	S15						
I don't care	S5							
Not really	S2	S4						

Why did you enjoy or not enjoy the activity?

S2: Because I am going to be in the news maybe.

S4: I like gears.

S5: I enjoyed the activity just a little because it was too easy.

S6: Because there was a lot of measuring and math

S9: I thought

S15: It was not fun. (*Mentor Note: hated math)

11. RACING BOTS (03/21/13)

***<u>IMPORTANT NOTE</u>:

Non-producing surveys were used because we were out of producing surveys. The activity also ran late and many children did not have adequate time to complete the surveys thoroughly and thoughtfully.

Racing Bots (3/21/13)								
Did you enjoy the activity?								
Very Much	S2	S9	S15					
Just a little	S6							
Not at all	S5							
Why? <u>S2</u>: Because I'm awesome. [*Mentor Note: Velocity's team won the first race.] <u>S4</u>: I like robot races. <u>S5</u>: Because the robot broke a lot, I was very upset. <u>S6</u>: Because mine kept on falling apart. <u>S9</u>: It was fun <u>S15</u>: It was fun								
Have you done a similar activity before?								
Yes	S2	S9						
Not Sure	S2	S6	S15					
No	S2	S4						
What area did the activity relate to?								
Science	S2	S6	S9					
Technology	S2	S4	S9					
Engineering	S2	S4	S6	S9	S15			
Math	S2							
Computer Science	S2	S9						
How? <u>S2</u>: Do not know the answer <u>S4</u>: Gears <u>S5</u>: [not answered] <u>S6</u>: Don't know <u>S9</u>: The tiny one [gear] will spin better <u>S15</u>: Because we had to build a robot.								

Give a real-life example where this could be applied								
S2: Do not know the answer S4: In a national robot race. S5: [not answered] S6: At a robot competition S9: NASCAR S15: Car, factory, and planes								
Would you like to learn more about this area?								
Yes, lots	S2	S4						
Yes, a little	S9							
I don't care	S6							
Not really	S15							

APPENDIX 7

A. MENTOR WEEKLY FEEDBACK SURVEY

Name: ____

Activity: ____

- Did the majority of the children respond positively to the activity?

Very much Some A little Not at all

- How much did the children struggle with the activity?

Very much Some Just a little Not at all

- Were they able to find a solution to the problem?

Yes Almost, they were on the right track They were hopelessly lost

- Did you have to provide advice?

Very much Just a little Not at all

- Did you have to provide hands-on assistance?

Very much Just a little Not at all

- Do you think the activity was effective?

Yes, completely Sort of, but needs tweaking Not at all

- If it needs tweaking, what would you change?

____

____

____

____

____

____

B. MENTOR WEEKLY FEEDBACK RESULTS

1. LINKAGES (11/29/12)

Linkages (11/29/12)				
Did the majority of the children respond positively to the activity?				
Very much	M4			
Some				
A little	M3			
Not at all				
How much did the children struggle with the activity?				
Very much	M3			
Some	M4			
Just a little				
Not at all				
Were they able to find a solution to the problem?				
Yes	M4			
Almost, they were on the right track				
They were hopelessly lost	M3			
Did you have to provide advice?				
Very much	M3			
Just a little	M4			
Not at all				
Did you have to provide hands-on assistance?				
Very much	M3			
Just a little				
Not at all	M4			
Do you think the activity was effective?				
Yes, completely	M4			
Sort of, but needs tweaking				
Not at all	M3			
If it needs tweaking, what would you change? M3: Don't do it!				

2.VACUUM GRIPPER (11/29/12)

Vacuum Gripper (11/29/12)				
Did the majority of the children respond positively to the activity?				
Very much	M2			
Some				
A little				
Not at all				
How much did the children struggle with the activity?				
Very much				
Some				
Just a little	M2			
Not at all				
Were they able to find a solution to the problem?				
Yes				
Almost, they were on the right track	M2			
They were hopelessly lost				
Did you have to provide advice?				
Very much				
Just a little	M2			
Not at all				
Did you have to provide hands-on assistance?				
Very much	M2			
Just a little				
Not at all				
Do you think the activity was effective?				
Yes, completely	M2			
Sort of, but needs tweaking				
Not at all				
If it needs tweaking, what would you change? M2: No Answer				

3. KIT EXPLORATION/BUILD BASEBOT (12/06/12)

Build Basebot (12/6/12)				
Did the majority of the children respond positively to the activity?				
Very much				
Some	M1	M2	M3	
A little				
Not at all	M5			
How much did the children struggle with the activity?				
Very much				
Some	M1	M3	M5	
Just a little				
Not at all				
More than they should have	M2			
Were they able to find a solution to the problem?				
Yes	M1	M3		
Almost, they were on the right track	M2			
They were hopelessly lost	M5			
Did you have to provide advice?				
Very much	M2			
Just a little	M1	M3	M5	
Not at all				
Did you have to provide hands-on assistance?				
Very much	M2	M5		
Just a little	M1	M3		
Not at all				
Do you think the activity was effective?				
Yes, completely				
Sort of, but needs tweaking	M1	M2	M3	M5
Not at all				
If it needs tweaking, what would you change? M1: Instruction booklets are hard to follow. Too much hole counting and perspectives obscuring where pieces go. M2: We need to create our own robot and building plans. [Visual instructions provided are difficult for children to follow] M3: Perhaps step-by-step instructions M5: No Answer				

4. PROGRAMMING SHAPES (01/17/13)

Program Shapes (01/17/13)					
Did the majority of the children respond positively to the activity?					
Very much	M1	M2	M3	M6	M7
Some					
A little					
Not at all					
How much did the children struggle with the activity?					
Very much					
Some	M1	M2	M7		
Just a little	M3	M6			
Not at all					
Were they able to find a solution to the problem?					
Yes					
Almost, they were on the right track	M1	M2	M3	M6	M7
They were hopelessly lost					
Did you have to provide advice?					
Very much	M1	M7			
Just a little	M2	M3			
Not at all					
N/A	M6				
Did you have to provide hands-on assistance?					
Very much	M7				
Just a little	M1	M2	M3		
Not at all					
N/A	M6				
Do you think the activity was effective?					
Yes, completely	M1	M2	M3	M6	
Sort of, but needs tweaking	M7				
Not at all					
If it needs tweaking, what would you change? M1: N/A M2: N/A M3: N/A M6: N/A M7: Keeping them on task					

5. LINE FOLLOWING (01/24/13)

Line Following (01/24/13)					
Did the majority of the children respond positively to the activity?					
Very much	M2	M3	M7	M8	
Some	M5				
A little					
Not at all					
How much did the children struggle with the activity?					
Very much					
Some	M8				
Just a little	M2	M5	M7		
Not at all	M3				
Were they able to find a solution to the problem?					
Yes	M2	M3	M7		
Almost, they were on the right track	M5	M8			
They were hopelessly lost					
Did you have to provide advice?					
Very much					
Just a little	M2	M3	M5	M7	M8
Not at all					
Did you have to provide hands-on assistance?					
Very much	M2				
Just a little	M5	M7	M8		
Not at all	M3				
Do you think the activity was effective?					
Yes, completely	M2	M3	M5	M7	M8
Sort of, but needs tweaking					
Not at all					
If it needs tweaking, what would you change? M2: N/A M3: N/A M5: N/A M7: N/A M8: N/A					

6. BUMP SENSORS (01/31/13)

Bump Sensors (01/31/13)				
Did the majority of the children respond positively to the activity?				
Very much	M2	M8		
Some	M1			
A little	M3	M9		
Not at all				
How much did the children struggle with the activity?				
Very much	M1	M2	M9	
Some	M3			
Just a little	M8			
Not at all				
Were they able to find a solution to the problem?				
Yes				
Almost, they were on the right track	M1	M2	M8	M9
They were hopelessly lost	M3			
Did you have to provide advice?				
Very much	M1	M3	M9	
Just a little	M2	M8		
Not at all				
Did you have to provide hands-on assistance?				
Very much	M2			
Just a little	M1	M3	M8	M9
Not at all				
Do you think the activity was effective?				
Yes, completely	M8			
Sort of, but needs tweaking	M1	M2	M3	M9
Not at all				
If it needs tweaking, what would you change? M1: We spend more time trying to get the turning correct than the bump sensor and maze M2: we need an animation of a bot going through a maze M3: N/A M8: N/A M9: A video on how to turn a certain angle				

7. NUMBERED CUPS (01/31/13)

Numbered Cups (01/31/13)					
Did the majority of the children respond positively to the activity?					
Very much	M2	M4			
Some	M3	M8			
A little					
Not at all					
How much did the children struggle with the activity?					
Very much					
Some	M3	M8			
Just a little					
Not at all	M2	M4	M7		
Were they able to find a solution to the problem?					
Yes	M2	M3	M4	M7	M8
Almost, they were on the right track					
They were hopelessly lost					
Did you have to provide advice?					
Very much	M8				
Just a little	M2	M3	M4		
Not at all	M7				
Did you have to provide hands-on assistance?					
Very much	M7	M8			
Just a little	M2	M3	M4		
Not at all					
Do you think the activity was effective?					
Yes, completely	M2	M3	M4	M7	M8
Sort of, but needs tweaking					
Not at all					
If it needs tweaking, what would you change?					
M2: N/A M3: N/A M4: I liked it M7: N/A M8: N/A					

8. THREE SENSOR MAZE (02/07/13)

3 Sensor Maze (02/7/13)				
Did the majority of the children respond positively to the activity?				
Very much	M2	M7		
Some	M1			
A little				
Not at all	M9			
How much did the children struggle with the activity?				
Very much	M2	M9		
Some	M1	M7		
Just a little				
Not at all				
Were they able to find a solution to the problem?				
Yes				
Almost, they were on the right track	M1	M2	M7	
They were hopelessly lost	M8			
Did you have to provide advice?				
Very much	M1	M2	M7	M8
Just a little				
Not at all				
Did you have to provide hands-on assistance?				
Very much	M7	M8		
Just a little	M1	M2		
Not at all				
Do you think the activity was effective?				
Yes, completely	M1	M2		
Sort of, but needs tweaking	M7	M8		
Not at all				
If it needs tweaking, what would you change? M1: tape the boxes down M2: N/A M7: workable field + equipment M8: Make this one easier, maybe larger groups so certain kids who understand it can teach their peers				

9. MILLION DOLLAR PROJECT (03/14/13)

Million Dollar Project (03/14/13)				
Did the majority of the children respond positively to the activity?				
Very much	M10			
Some	M1	M2		
A little				
Not at all				
How much did the children struggle with the activity?				
Very much				
Some	M10			
Just a little	M1	M2		
Not at all				
Were they able to find a solution to the problem?				
Yes	M10			
Almost, they were on the right track	M1	M2		
They were hopelessly lost				
Did you have to provide advice?				
Very much	M1	M2		
Just a little	M10			
Not at all				
Did you have to provide hands-on assistance?				
Very much	M1	M2		
Just a little	M10			
Not at all				
Do you think the activity was effective?				
Yes, completely	M10			
Sort of, but needs tweaking	M1	M2		
Not at all				
If it needs tweaking, what would you change? M1: Different businesses. Greater variety of prices between options in same category M2: Some of the younger kids don't know how to divide M10: Develop different businesses so it can be repeated other times (since kids seems to enjoy it a lot)				

10. INTRO TO GEARS (03/21/13)

Intro to Gears (03/21/13)					
Did the majority of the children respond positively to the activity?					
Very much	M2	M5	M6		
Some	M1	M9	M10		
A little	M4				
Not at all					
How much did the children struggle with the activity?					
Very much	M1	M2	M10		
Some	M4	M5	M6	M9	
Just a little					
Not at all					
Were they able to find a solution to the problem?					
Yes	M2	M5	M6		
Almost, they were on the right track	M1	M4	M9	M10	
They were hopelessly lost					
Did you have to provide advice?					
Very much	M9	M10			
Just a little	M1	M2	M4	M5	M6
Not at all					
Did you have to provide hands-on assistance?					
Very much	M9	M10			
Just a little	M1	M2	M4	M5	M6
Not at all					
Do you think the activity was effective?					
Yes, completely	M2	M6	M9		
Sort of, but needs tweaking	M1	M4	M5	M10	
Not at all					

If it needs tweaking, what would you change?

M1: Some students very resistant to math, measuring got very repetitive and boring.
M2: Some of the younger kids don't know how to divide
M4: Better explanation of objectives
M5: A bit on angles and how to measure them
M6: [blank]
M9: Pre-drawn measurement lines
M10: [blank]

11. RACING BOTS (03/21/13)

Racing Bots (03/21/13)					
Did the majority of the children respond positively to the activity?					
Very much	M1	M2	M5	M6	M10
Some					
A little					
Not at all	M9				
How much did the children struggle with the activity?					
Very much	M2	M9			
Some	M5	M6	M10		
Just a little	M1				
Not at all					
Were they able to find a solution to the problem?					
Yes	M1	M2	M6	M10	
Almost, they were on the right track	M5	M9			
They were hopelessly lost					
Did you have to provide advice?					
Very much	M6	M9			
Just a little	M1	M2	M5	M10	
Not at all					
Did you have to provide hands-on assistance?					
Very much	M6	M9	M10		
Just a little	M1	M2	M5		
Not at all					
Do you think the activity was effective?					
Yes, completely	M1	M2	M10		
Sort of, but needs tweaking	M5	M6	M9		
Not at all					

If it needs tweaking, what would you change?

M1: Robots need to be built sturdier!
M2: Better racing botsM5: Go over it again so they understand the reason to use the opposite side
M6 More time
M9: Provide options to build, have them choose which one is better, then build it. The girls I was with just didn't like legos. [*Note: Their robot kept breaking apart into pieces too.]
M10: [blank]

APPENDIX 8

A. RESEARCHER WEEKLY FEEDBACK SURVEY

Name: ____

Activity: ____

- Students:

  - Basic Effectiveness:

I. Were the kids paying attention and not running around, texting, etc.?

1 (mad house) 2 3 4 5 (very focused)

II. Can the activity be explained in less than 15 minutes?

1 (5+ minutes over) 3 (less than 5 over) 5 (15 minutes or less)

III. Can the activity (or a full section of it) be completed in less than 45 minutes?

1 (10+ minutes over) 3 (less than 10 over) 5 (45 minutes or less)

  - High Effectiveness:

IV. Were the kids able to understand the instructions and what was asked of them?

1 (high confusion) 2 4 (some clarification) 5 7 (clear, understandable)

V. Did kids keep trying/not give up and did they find a viable solution?

1 (majority gave up)

2 (some gave up, or were distracted, mentors provided significant guidance, prodding)

3 (some prodding needed, some students had no solution, some did or were close)

5 (students needed no prodding, were engaged, majority did not find good solution)

7 (students needed no prodding, majority were able to solve challenge)

- Prep Work:

VI. Can the prep work be completed in 1-2 hours? OR Can prep work be reused year to year with repairs/maintenance taking under an hour?

1 (3+ hr or 2+ annual)   3 (2-3 hr or 1-2hr annual)   5 (<2 hr or <1 annual)

- College Mentors:
  - Basic Effectiveness:

VII. Were the mentors able to explain the lesson in a way the kids could understand?

1 (Not at all)   2   3 (some confusion)   4   5 (clear, can answer questions)

VIII. Were the mentors able to engage and talk with the students?

1 (Sat in corner)   2   3 (some guidance)   4   5 (good guiding questions)

- High Effectiveness:

IX. Did the mentors guide the students by asking questions rather than telling them what to do?

1 (told)   2   4 (mix of told and asked)   5   7 (asked)

X. Did the mentors enjoy helping with the activity?

1 (not at all)   2   3   5   7 (very much)

B. RESERACHERS WEEKLY RESULTS

1. DETAILED RESEARCHER FEEDBACK SURVEY RESULTS

		Survey Questions											
Activity:	**R**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**Total**	**%**
Max possible	**n/a**	**5**	**5**	**5**	**7**	**7**	**5**	**5**	**5**	**7**	**7**	**58**	**100%**
Vacuum Gripper (11/29/12)	R1	4	5	5	7	n/a	5	5	4	4	5	44	75.9%
Build Basebot (12/6/12)	R1	3	5	1	2	2	5	4	4	2	3	31	53.4%
Program Shapes (1/17/13)	R1	4	5	3	7	6	1	5	4	4	7	46	79.3%
Program Shapes (1/17/13)	R2	4	5	3	7	6	1	5	5	5	7	48	82.8%
Human Sensors (1/24/13)	R1	4	5	5	4	6	5	4	2	1	3	39	67.2%
Human Sensors (1/24/13)	R2	3	5	5	4	7	5	5	3	4	3	44	75.9%
Line Following (1/24/13)	R1	4	5	5	4	7	4	3	4	4	5	45	77.6%
Line Following (1/24/13)	R2	5	5	3	5	6	3	4	5	6	7	49	84.5%
Bump Sensor (1/31/13)	R1	4	5	1	5	5	5	4	4	4	5	42	72.4%
Bump Sensor (1/31/13)	R2	4	5	1	4	2	5	4	3	4	5	37	63.8%

Numbered Cups (1/31/13)	R1	5	5	5	4	7	5	4	3	4	5	47	81.0%
Numbered Cups (1/31/13)	R2	4	5	5	6	7	5	5	4	6	6	53	91.4%
3 Sensor Maze (2/7/13)	R1	5	5	1	4	3	5	4	4	6	6	43	74.1%
3 Sensor Maze (2/7/13)	R2	5	5	1	5	5	5	5	5	6	7	49	84.5%
Million Dollar (3/14/13)	R1	4	5	4	4	5	3	4	3	4	5	41	70.7%
Million Dollar (3/14/13)	R2	5	5	5	7	6	5	5	5	6	6	55	94.8%
Intro to Gears (3/21/13)	R1	4	4	4	5	4	1	5	4	1	5	37	63.8%
Intro to Gears (3/21/13)	R2	4	5	3	4	4	5	4	3	4	4	40	69.0%
Racing Bots (3/21/13)	R1	5	5	5	7	7	3	4	3	2	7	48	82.8%
Racing Bots (3/21/13)	R2	5	5	5	7	7	5	4	3	4	7	52	89.7%

2. AVERAGED RESEARCHER FEEDBACK SURVEY RESULTS

Activity:	Average Score	Percentage
Max possible	**58**	**100%**
Vacuum Gripper (11/29/12)	44	80%
Build Basebot (12/6/12)	31	53.4%
Program Shapes (1/17/13)	47	81%
Human Sensors (1/24/13)	41.5	71.6%
Line Following (1/24/13)	47	81%
Bump Sensor (1/31/13)	39.5	68.1%
Numbered Cups (1/31/13)	50	86.2%
3 Sensor Maze (2/7/13)	46	79.3%
Million Dollar (3/14/13)	48	82.8%
Intro to Gears (3/21/13)	38.5	66.4%
Racing Bots (3/21/13)	50	86.2%

C. RESERACHERS' OBSERVATIONS

1. KIT EXPLORATION/BUILD BASEBOT (12/06/12)

Name: Carly

Date: 12/6/2012

Activity: Build Basebot

Observations:

Intended activity was to use LEGO Bots I lesson plan to teach programming for both first and second hour. However, kits (6) from Robotics Center did not include enough batteries or brains. There were also only three (3) laptops from the ATC.

Plan was changed to have students build basebots for the first hour and then make up some activity for the second hour. Students were to build basebots in 3 groups of about 4 students each. They were following LEGO NXT instruction booklets. Significant difficulties arose around the booklets: Students did not share the booklet or materials within their group The instruction booklets were entirely pictorial. Students had a hard time understanding them. In particular, the diagrams often showed the project at an angle, which obscured certain details and used exploded format with arrows indicating where parts should go. Students did not understand how to read these diagrams. The instruction booklets often required to count holes both in the picture and then in the physical blocks. Inaccuracy in these actions tripped up students and mentors alike.

Prior to attendance by researcher, students were “yelled at” for being too noisy by an adult running a conference in the odium across the hallway. Apparently the students were quieter and more focused after this incident.

Source: Ennio

Approximately one-third (1/3) of the students in attendance were rookies who had never used the kits before. These students struggled through the instructions for longer, but frequently gave up and talk to their peers or watch out the windows, etc. before a mentor would come by to help them for a period.

As it became apparent no basebot would be finished in an hour, and other robots began to emerge (see point below), the mentors decided it would be best to allow the children to continue exploring the kits and experimenting. Experienced students quickly began building their own crank-powered robots, heedless of the instructions.

When these robots began to become sophisticated, students were encouraged to attach a brain and were then given a laptop and told to experiment with programming their robots. Ennio: “When allowed to build anything, the students build the same thing over and over, every year.”

Velocity programmed her robot to “dance” i.e. spin in circles. Students did not integrate sensors into their robots, but kept to just motors.

There was no official dinner break. Students were allowed to eat whenever they wanted to or needed a break from working.

Rookie students eventually realized their peers were having more fun building custom robots. They attempted to join in, but by that point they did not have enough time or remaining parts to build a complete robot.

Conclusions:

If students are expected to build from instructions, better instructions are needed.

"Kit exploration" activity could be a good one, so long as students are explicitly instructed to experiment

WARNING: Causes SEVERE kit disorganization

Approx 2hrs for 2 people to sort 6 kits

2. PROGRAMMING SHAPES (01/17/13)

Name: Julieth

Date: 01/17/13

Activity: Programming Shapes

Observations:

The kids complained a lot for having to fill out the general survey at the beginning of the session; they said it was too long (one page front and back). The majority of them were frustrated with some of the questions since they had no clue what to answer. They reached out to mentor for help with answering the survey, especially with trying to find out what technology was and who were examples of scientists and engineers. Some of them decided to make up random names to no leave the question blank; they claimed that since the names did not really exist, they could possibly fool the mentors when grading the survey. Many of them do not know what technology is other than computers and cell phones.

While they were completing the survey, mentors were installing the require software to conduct the programming activity. However, the installation process took too long and the kids finished the survey before the mentors were ready to begin the programming activity. Kids started to get distracted, running around the classroom and being very noisy. In order to distract them while the software installation process, Cat brought napkins and started an OM challenge with the kinds and two other mentors. The challenge engaged them very well; they tried to fold the napkin into as many pieces as possible and also went around in a circle trying to come up with different things a napkin could be used for (hat, flower, bag, etc.)

Once the software installation was completed, the activity began with the kids being divided into three teams of three. There were three new kids who were grouped into one of the teams of three. This time, since the groups were smaller, all three kids in each team had a better chance to learn and contribute to the challenge. In addition, we had at least one mentor per group, which facilitated the tutoring of the mentor with more engaging methods than just providing the answer to the problems. Overall, the activity was very successful, however some of the experienced kids got a little frustrated when paired with inexperienced kids. This indicated that it would be better for future activities to arrange the groups such that experienced kids can either work with other experienced kids or alone. It would also be ideal if different assignments with different level of complexity were given to each team such that experienced kids were more challenged, thus avoiding frustration and boredom. It would also be better to do the group and assignment distribution by numbers and in a way that each team works on something different so that those kids with the easier assignments don't feel bad.

Conclusions:

- Smaller groups work better
- Form groups according to level of experience
- Have different assignments for each group so that match their level of experience
- Group and assignment distribution should seem random to the kids
- Have more short activities prepared for unexpected cases
- Programming activities should last a whole session (2 hours) so that kids have more time to develop theories and test them, thus having a better learning experience
- Find a better solution for the software installation so programming activity can begin on time

3.LINE FOLLOWING (01/24/13)

Name: Julieth

Date: 01/24/13

Activity: Line Following

Observations:

We continue to have more mentors attending the Robokids session. This, I believe, is in part what has made possible that activities turn out to be more successful than last term since we can now assign one mentor per group of two or three students. However, some of the new mentors are not familiar with the material they are expected to teach the students. In addition we have noticed that not only the new mentors but also the old ones need to be trained on how to actually mentor the kids rather than easily providing them with the answers to the challenge or simply solving it themselves. We have concluded that in order to solve this issue we would need to email the lesson plans of the activities to the mentors so they can become familiar with it ahead of time rather than trying to figure it out at the actual Robokids session. We would also need to schedule mentor training meetings to guaranteed proper mentoring skills so that the kids can learn and produce more themselves rather than observe.

The “Human Sensor” activity did not seem too successful. The kids rushed through it with little enthusiasm. Once finished, they got distracted with the process of rearranging the tables that have been used to create the maze. This conflicted with the mentor leading the activity (Carly) who was trying to catch their attention by explaining the relation of this activity to robotics.

The videos shown during the dinner break seem to attract the kids greatly. The "planetary gears" video was in fact their favorite.

The "Line Following" activity turned out to be very successful in terms of engaging the kids. However, I would not say exactly the same about the learning outcome factor. I observed that many of the groups relied a lot on the mentors' solutions to the challenge rather than developing their own strategies and gaining a full understanding of how did the program truly worked on the robot to allow it to follow the lines.

After the main part of the "Line Following" activity was completed, several small lines of duct tape were used to create some sort of messy maze inside the main circle that was used for the "Line Following." The purpose of this was to have the kids test their robots inside the maze and make sure their robots would avoid crossing the small lines of duct tape that were spread all around. Some groups immediately went ahead to try to solve this new challenged. Others decided to have their robots perform the previous challenge ("Line Following") at an even faster rate. Again, with the help of the mentors, some of them were able to master this new challenge.

Conclusions:

- Mentors need to become familiar with the activity before the actual Robokids session. We need to email them the lesson plans ahead of time.
- Mentor MUST acquire some training as soon as possible so they can have a Q&A interaction with the kids rather than just providing answers.

APPENDIX 9

A. TALLIED MENTOR HIGH/MED/LOW REPONSES

		Linkages	Kit Explore	Shapes	Line	Bump	Cups	3 Maze	Million Dollar	Intro Gears	Racing Bots
Total Mentors	**Total Mentors**	2	4	5	5	5	6	4	3	7	6
Positive	**Positive**										
High	Very much	1	0	5	4	2	3	2	1	3	5
Med	Some	0	3	0	1	1	3	1	2	3	0
Med	A little	1	0	0	0	2	0	0	0	1	0
Low	Not at all	0	1	0	0	0	0	1	0	0	1
Struggle	**Struggle**										
Low	Very much	1	4	0	0	3	0	2	0	3	2
High	Some	1	0	3	1	1	2	2	1	4	3
High	Just a little	0	0	2	3	1	1	0	2	0	1
Med	Not at all	0	0	0	1	0	3	0	0	0	0
Solution	**Solution**										
Med	Yes	1	2	0	3	0	6	0	1	3	4
High	Almost	0	1	5	2	4	0	3	2	4	2
Low	Lost	1	1	0	0	1	0	1	0	0	0
Advice	**Advice**										
Low	Very much	1	1	2	0	3	2	4	2	2	2
High	Just a little	0	3	2	5	2	3	0	1	5	4
Med	Not at all	1	0	0	0	0	1	0	0	0	0
Assistance	**Assistance**										
Low	Very much	1	2	1	1	1	0	2	2	2	3
Med	Just a little	0	2	3	3	4	3	2	1	5	3
High	Not at all	1	0	0	1	0	3	0	0	0	0
Effective	**Effective**										
High	Completely	1	0	4	5	1	5	2	1	3	3
Med	Tweaking	0	4	1	0	4	1	1	2	4	3
Low	Not at all	1	0	0	0	0	0	1	0	0	0

B. TALLIED RESEARCHERS HIGH/MED/LOW RESPONSES

		Linkages	Kit Explore	Shapes	Line	Bump	Cups	3 Maze	Million Dollar	Intro Gears	Racing Bots
	Total Researchers	0	1	2	2	2	2	2	2	2	2
1	**Attention**										
Low	1,2	0	0	0	0	0	0	0	0	0	0
Med	3	0	1	0	0	0	0	0	0	0	0
High	4,5	0	0	2	2	2	2	2	2	2	2
3	**Completed**										
Low	1,2	0	1	0	0	2	0	2	0	0	0
Med	3	0	0	2	1	0	0	0	0	1	0
High	4,5	0	0	0	1	0	2	0	2	1	2
4	**Understand**										
Low	1,2	0	1	0	0	0	0	0	0	0	0
Med	3,4	0	0	0	1	1	1	1	1	1	0
High	5,6,7	0	0	2	1	1	1	1	1	1	2
5	**Persistence/ Solution**										
Low	1,2	0	1	0	0	0	0	0	0	0	0
Med	3,4	0	0	0	0	0	0	1	0	2	0
High	5,6,7	0	0	2	2	2	2	1	2	0	2

C.TALLIED STUDENT HIGH/MED/LOW RESPONSES

		Linkages	**Kit Explore**	**Shapes**	**Line**	**Bump**	**Cups**	**3 Maze**	**Million Dollar**	**Intro Gears**	**Racing Bots**
	Total Kids	8	5	9	11	11	11	8	9	6	5
	Enjoy										
High	Very Much	1	4	8	7	5	7	5	8	2	3
Med	Just a little	7	1	1	3	3	2	3	1	3	1
Low	Not at all	0	0	0	1	3	2	0	0	1	1
	Difficult										
Low	Very Hard	0	0	0	2	2		2	1	0	
High	Sort of Hard	6	2	4	3	7		3	2	2	
High	Neither hard or easy	1	1	2	2	2		1	2	1	
Med	Sort of Easy	0	0	2	2	0		1	3	0	
Low	Very Easy	1	2	1	2	0		2	1	3	
	Finish										
Med	Yes, with extra	3	3	2	3	2		0	4	3	
High	Yes, barely	1	1	7	6	2		3	5	2	
Med	No, but close	2	0	0	1	4		3	0	1	
Low	No, not close	2	1	0	0	3		2	0	0	
	Change Difficulty										
Med	Yes, harder	0	2	1	2	2		2	1	3	
High	No, the same	2	1	7	4	4		4	7	1	
Low	Yes, easier	6	2	1	4	5		2	1	2	
	Learn More										
High	Yes, lots	2	2	3	4	2	5	2	6	3	2
Med	Yes, a little	5	1	6	3	4	2	4	3	2	1
Low	I don't care	0	2	0	3	3	2	2	0	1	1
Low	Not really	1	0	0	1	2	1	0	0	0	1

***IMPORTANT NOTE:

Non-producing surveys were used for Racing Bots because we were out of producing surveys. The activity also ran late and many children did not have adequate time to complete the surveys thoroughly and thoughtfully.

D. TALLIED MENTOR + RESEARCHERS HIGH/MED/LOW RESPONSES

	Linkages	Kit Explore	Shapes	Line	Bump	Cups	3 Maze	Million Dollar	Intro Gears	Racing Bots
Independence										
High	0.5	1	5	5	4	4.25	2.25	3.25	1.25	3.25
Med	0.5	1	0.75	1.75	1	3.25	1.5	0.5	2.5	0.5
Low	1	3	0.75	0.25	2	0.5	2.25	2.25	2.25	2.25
Effectiveness										
High	1	0	5	6	1.5	6.5	2.5	2.5	4	5
Med	0	4	1	0	4	1	2	2	6	3
Low	1	1	0	0	0	0	1	0	0	0
Enjoyment										
High	1	0	7	6	4	5	4	3	5	7
Med	1	4	0	1	3	3	1	2	4	0
Low	0	1	0	0	0	0	1	0	0	1

APPENDIX 10

A. MENTOR HIGH/MED/LOW PERCENTAGES

	Linkages	Kit Explore	Shapes	Line	Bump	Cups	3 Maze	Million Dollar	Intro Gears	Racing Bots
Independence										
High	25.0%	25.0%	60.0%	60.0%	40.0%	37.5%	31.3%	50.0%	46.4%	41.7%
Med	25.0%	25.0%	15.0%	35.0%	20.0%	54.2%	12.5%	16.7%	28.6%	29.2%
Low	50.0%	50.0%	15.0%	5.0%	40.0%	8.3%	56.3%	33.3%	25.0%	29.2%
Effectiveness										
High	50.0%	0.0%	80.0%	100.0%	20.0%	83.3%	50.0%	33.3%	42.9%	50.0%
Med	0.0%	100.0%	20.0%	0.0%	80.0%	16.7%	25.0%	66.7%	57.1%	50.0%
Low	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%
Enjoyment										
High	50.0%	0.0%	100.0%	80.0%	40.0%	50.0%	50.0%	33.3%	42.9%	83.3%
Med	50.0%	75.0%	0.0%	20.0%	60.0%	50.0%	25.0%	66.7%	57.1%	0.0%
Low	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	16.7%

B. RESEARCHERS HIGH/MED/LOW PERCENTAGES

	Linkages	Kit Explore	Shapes	Line	Bump	Cups	3 Maze	Million Dollar	Intro Gears	Racing Bots
Independence										
High	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%	50.0%	100.0%	0.0%	100.0%
Med	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	100.0%	0.0%
Low	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Effectiveness										
High	0.0%	0.0%	50.0%	50.0%	25.0%	75.0%	25.0%	75.0%	50.0%	100.0%
Med	0.0%	0.0%	50.0%	50.0%	25.0%	25.0%	25.0%	25.0%	50.0%	0.0%
Low	0.0%	100.0%	0.0%	0.0%	50.0%	0.0%	50.0%	0.0%	0.0%	0.0%
Enjoyment										
High	0.0%	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Med	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Low	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

C. STUDENT HIGH/MED/LOW PERCENTAGES

	Linkages	Kit Explore	Shapes	Line	Bump	Cups	3 Maze	Million Dollar	Intro Gears	Racing Bots
Independence										
High	42.1%	33.6%	74.0%	45.5%	45.8%	0.0%	45.9%	59.1%	33.5%	0.0%
Med	8.3%	13.2%	11.2%	15.2%	18.0%	0.0%	24.9%	15.0%	22.0%	0.0%
Low	37.3%	33.4%	7.4%	24.4%	30.2%	0.0%	33.5%	11.2%	28.0%	0.0%
Effectiveness										
High	25.0%	40.0%	33.3%	36.4%	18.2%	45.5%	25.0%	66.7%	50.0%	40.0%
Med	62.5%	20.0%	66.7%	27.3%	36.4%	18.2%	50.0%	33.3%	33.3%	20.0%
Low	12.5%	40.0%	0.0%	36.4%	45.5%	27.3%	25.0%	0.0%	16.7%	40.0%
Enjoyment										
High	12.5%	80.0%	88.9%	63.6%	45.5%	63.6%	62.5%	88.9%	33.3%	60.0%
Med	87.5%	20.0%	11.1%	27.3%	27.3%	18.2%	37.5%	11.1%	50.0%	20.0%
Low	0.0%	0.0%	0.0%	9.1%	27.3%	18.2%	0.0%	0.0%	16.7%	20.0%

D. MENTOR + RESEARCHER HIGH/MED/LOW PERCENTAGES

	Linkages	Kit Explore	Shapes	Line	Bump	Cups	3 Maze	Million Dollar	Intro Gears	Racing Bots
Independence										
High	38.7%	26.8%	72.9%	55.6%	50.2%	22.4%	42.3%	61.2%	21.7%	25.0%
Med	11.6%	16.6%	11.0%	19.0%	16.6%	17.1%	24.9%	13.2%	25.5%	3.8%
Low	39.8%	46.7%	8.9%	16.3%	29.6%	2.6%	35.2%	23.3%	26.2%	17.3%
Effectiveness										
High	30.0%	20.0%	50.0%	55.6%	19.4%	60.5%	32.1%	60.7%	46.7%	53.8%
Med	50.0%	50.0%	43.8%	16.7%	44.4%	15.8%	42.9%	35.7%	53.3%	30.8%
Low	20.0%	30.0%	0.0%	22.2%	27.8%	15.8%	21.4%	0.0%	6.7%	15.4%
Enjoyment										
High	20.0%	40.0%	93.8%	72.2%	50.0%	63.2%	64.3%	78.6%	46.7%	76.9%
Med	80.0%	50.0%	6.3%	22.2%	33.3%	26.3%	28.6%	21.4%	46.7%	7.7%
Low	0.0%	10.0%	0.0%	5.6%	16.7%	10.5%	7.1%	0.0%	6.7%	15.4%

APPENDIX 11

A. STUDENTS GENERAL FEEDBACK SURVEY

Name: ____ Grade: ______________

1) Do you learn about Science, Technology, Engineering, and Math in school?

   Very much   Just a little   Not at all

2) Do you enjoy your schoolwork?

   Very much   Just a little   Not at all

3) How interested are you in Science, Technology, Engineering, and Math outside of school?

   Very interested   Fairly interested   Not so much interested   Not interested at all

4) Are you familiar with technology?

   Very much   Just a little   Not at all

5) Do you know how to use a computer?

   Very much   Just a little   Not at all

6) Do you know how to use a cell phone?

   Very much   Just a little   Not at all

7) Do you build things?

   Very much   Just a little   Not at all

8) Do you take machines, appliances, or electronics apart to see how they work?

   Very much   Just a little   Not at all

9) Are you interested in computer science? Please circle one of:

Very much   Just a little   Not at all

10) Are you interested in programming? Please circle one of:

Very much   Just a little   Not at all

11) Are you interested in engineering? Please circle one of:

Very much   Just a little   Not at all

12) Are you interested in designing buildings, machines, planes, robots, or electronics?

Very much   Just a little   Not at all

13) Are you interested in science? Please circle one of:

Very much   Just a little   Not at all

14) Are you interested in learning about the Earth, outer space, animals, plants, rocks, or chemicals?

Very much   Just a little   Not at all

15) Is technology important? Please circle one of:

Very much   Just a little   Not at all

16) Can technology change the world? Please circle one of:

Very much   Just a little   Not at all

17) What is an example of important technology? Why is it important?

____
____
____
____

18) Can you name a scientist?

____

19) Can you name an engineer?

____

20) Do you like coming to the Robokids sessions? Please circle one of:

Very much Just a little Not at all

21) Are you learning at the Robokids sessions? Please circle one of:

I am learning a lot I am learning a little I am not learning anything

22) Have you ever learned the same thing at Robokids and at school? Please circle one of:

Very much Just a little Not at all

23) Do you like the variety of activities you do at the Robokids sessions? Please circle one of:

Yes, they are different and interesting Just a little, they are not very interesting

Not really, they are somewhat repetitive Not at all, they are boring

24) Has Robokids taught you about science?

Very much Just a little Not at all

25) Has Robokids taught you about computers?

Very much Just a little Not at all

26) Has Robokids taught you about robots?

Very much Just a little Not at all

27) Has Robokids taught you about technology other than computers and robots?

Very much Just a little Not at all

28) Has Robokids taught you about math?

Very much Just a little Not at all

29) Will you keep coming to Robokids?

Very much Just a little Not at all

B. STUDENTS GENERAL FEEDBACK SURVEY RESULT

Do you learn about STEM in school?									
Very Much	S2								
Just a Little	S3	S4	S9	S11	S15	S16	S17	S18	
Not at all									
Do you enjoy your schoolwork?									
Very much	S2	S11	S16	S17					
Just a little	S9	S15							
Not at all	S4	S18							
N/A	S3								
How interested are you in STEM outside of school?									
Very interested	S4	S15	S17	S18					
Fairly Interested	S2	S3							
Not so much	S9	S11	S16						
Not at all									
Are you familiar with technology?									
Very much	S4	S11	S18						
Just a little	S2	S3	S9	S17					
Not at all	S15	S16							
Do you know how to use a computer?									
Very much	S2	S3	S4	S9	S11	S15	S16	S17	S18
Just a little									
Not at all									
Do you know how to use a cell phone?									
Very much	S2	S3	S4	S9	S11	S15	S17	S18	
Just a little	S16								
Not at all									
Do you build things?									
Very much	S2	S4	S15	S17	S18				
Just a little	S9	S11	S16						
Not at all	S3								
Do you take machines, appliances, or electronics apart to see how they work?									
Very much	S18								
Just a little	S2	S17							
Not at all	S3	S4	S9	S11	S15	S16			
Are you interested in computer science?									
Very much	S2	S4	S15	S18					
Just a little	S3	S9	S17						
Not at all	S11	S16							

Are you interested in programming?									
Very much	S4	S15	S17	S18					
Just a little	S2	S3	S9	S11	S16				
Not at all									
Are you interested in engineering?									
Very much	S4	S15	S17						
Just a little	S2	S3	S9	S11	S18				
Not at all	S16								
Are you interested in designing buildings, machines, planes, robots, or electronics?									
Very much	S2	S4	S9	S15	S16	S17	S18		
Just a little	S3								
Not at all	S11								
Are you interested in science?									
Very much	S2	S3	S4	S15	S18				
Just a little	S9	S11	S16	S18					
Not at all									
Are you interested in learning about the Earth, outerspace, animals, plants, rocks, or chemicals?									
Very much	S2	S3	S4	S9	S16	S17	S18		
Just a little	S11	S15							
Not at all									
Is technology important?									
Very much	S2	S4	S9	S11	S15	S17	S18		
Just a little	S3	S16							
Not at all									
Can technology change the world?									
Very much	S2	S4	S9	S11	S15	S17	S18		
Just a little	S3								
Not at all	S16								
Do you like coming to the Robokids sessions?									
Very much	S3	S4	S9	S15	S18				
Just a little	S2	S11	S16	S17					
Not at all									
Are you learning at the Robokids sessions?									
A lot	S3	S4	S9	S17					
A little	S2	S15	S16	S18					
Not at all									
N/A	S11								
Have you ever learned the same thing at Robokids and at school?									
Very much	S2	S4	S11						
Just a little	S9								
Not at all	S3	S15	S16	S17	S18				

Do you like the variety of activities you do at the Robokids sessions?									
Yes, different and interesting	S3	S4	S15	S17	S18				
A little, not very interesting	S11	S16							
Not really, repetitive	S2	S9							
Not at all, boring									
Has Robokids taught you about science?									
Very much	S3	S4	S9	S16					
A little	S2	S11	S15	S17	S18				
Not at all									
Has Robokids taught you about computers?									
Very much	S3	S4	S11						
A little	S15	S16	S17						
Not at all	S2	S9	S18						
Has Robokids taught you about robots?									
Very much	S2	S4	S9	S11	S15	S17			
A little	S3	S16							
Not at all	S18								
Has Robokids taught you about technology other than computers and robots?									
Very much	S3	S4	S9	S11	S17				
Just a little	S16								
Not at all	S2	S15	S18						
Has Robokids taught you about math?									
Very much	S4								
Just a little	S3	S9	S11						
Not at all	S2	S15	S16	S17	S18				
Will you keep coming to Robokids?									
Very much	S3	S9	S15	S18					
Just a little	S2	S11	S16	S17					
Not at all									
?	S4								

Can you name a scientist?

S2: teachers, Abert Einstein, Bill Nye, Mrs. Weagle

S3, S4: Einstein

S9: Leonardo de Vinci

S18: Ben Franklin

S11, S15, S16, S17: ?

Can you name an engineer?
S9: Ben Franklin S11: Gustav Climit S18: Quston S2, S3, S4, S15, S16, S17: ?
What is an example of important technology? Why is it important?
S2: computers/cell phones S3: An computer is a important because you could look up something. S4: The future it is easier for humans S9: A example of important technology is artificial limbs S11: Flying cars because you can travel to destinations faster. S15: To learn about technology S16, S17: ? S18: We wouldn’t have any light or no markets and dirty clothes

APPENDIX 12

A. TALLIED HIGH/MED/LOW RESPONSES REGARDING ROBOKIDS PROGRAM GENERAL PERCEPTION

	High	Med	Low
Science	4	5	0
Technology	4	2	3
Engineering	6	2	1
Math	1	3	5
Enjoyment	5	4	0
Learning	4	4	1
Variety of Activities	5	2	2
Attendance Motivation	4	4	1
Compatibility with School	5	1	3

B. TALLIED HIGH/MED/LOW RESPONSES REGARDING STUDENTS' STEM INTERETS AND ROBOKIDS' STEM OUTREACH

		High	Med	Low
Students' STEM Interests	**Science**	6	3	0
Robokids' STEM Outreach		4	5	0
Students' STEM Interests	**Technology**	4	4	1
Robokids' STEM Outreach		4	2	3
Students' STEM Interests	**Engineering**	4	3	2
Robokids' STEM Outreach		6	2	1
Students' STEM Interests	**Math**	N/A	N/A	N/A
Robokids' STEM Outreach		1	3	5

APPENDIX 13

A. HIGH/MED/LOW PERCENTAGES REGARDING ROBOKIDS PROGRAM GENERAL PERCEPTION

	High	Med	Low
Science	44.44%	55.56%	0.00%
Technology	44.44%	22.22%	33.33%
Engineering	66.67%	22.22%	11.11%
Math	11.11%	33.33%	55.56%
Enjoyment	55.56%	44.44%	0.00%
Learning	44.44%	44.44%	11.11%
Variety of Activities	55.56%	22.22%	22.22%
Attendance Motivation	44.44%	44.44%	11.11%
Compatibility with School	55.56%	11.11%	33.33%

B. HIGH/MED/LOW PERCENTAGES REGARDING STUDENTS' STEM INTERETS AND ROBOKIDS' STEM OUTREACH

		High	Med	Low
Students' STEM Interests	**Science**	66.67%	33.33%	0.00%
Robokids' STEM Outreach		44.44%	55.56%	0.00%
Students' STEM Interests	**Technology**	44.44%	44.44%	11.11%
Robokids' STEM Outreach		44.44%	22.22%	33.33%
Students' STEM Interests	**Engineering**	44.44%	30.56%	25.00%
Robokids' STEM Outreach		66.67%	22.22%	11.11%
Students' STEM Interests	**Math**	N/A	N/A	N/A
Robokids' STEM Outreach		11.11%	33.33%	55.56%

APPENDIX 14

A. EFFECTIVENESS CRITERIA FOR A SINGLE ACTIVITY

1. FROM PROPOSAL

- Did the majority of the participants enjoy the activity?
- Did the majority of the participants successfully complete the assignment within the given time frame?
- Did the majority of the participants consider that the level of difficulty of the given assignment was appropriate for their abilities?
- Were the majority of the participants satisfied with the supplies they were provided with?
- Would the majority of the participants be interested in engaging in more activities similar to the given assignment?

2. REVISED VERSION

- Students:
  - Basic Effectiveness:

I. Were the kids paying attention and not running around, texting, etc.?

II. Can the activity be explained in less than 15 minutes?

III. Can the activity (or a full section of it) be completed in less than 45 minutes?

➢ High Effectiveness:

IV. Were the kids able to understand the instructions and what was asked of them?

V. Were kids able to find a viable solution (if building/problem-solving activity)?

OR

If the kids were unable to find a solution, did they keep trying and not give up?

- Prep Work:

VI. Can the prep work be completed in 1-2 hours?

OR

Can prep work be reused year to year with repairs/maintenance taking under an hour?

- College Mentors:

➢ Basic Effectiveness:

VII. Were the mentors able to explain the lesson in a way the kids could understand?

VIII. Were the mentors able to engage and talk with the students?

➢ High Effectiveness:

IX. Did the mentors guide the students by asking questions rather than telling them what to do?

X. Did the mentors enjoy helping with the activity?

How to Use Lesson Plans 1

This chapter covers a general outline of how to read the lesson plans we created for the Robokids program. This information is repeated at the beginning of each lesson plan to make them stand alone entities.

Following the Lesson Plan

Background

Robokids is a program run at Worcester Polytechnic Institute (WPI) with Worcester Friendly House. Meetings are once a week, for two hours each, with children ages 7-12.

As part of our Interactive Qualifying Project (IQP), a graduation requirement at WPI focused on teaching engineers awareness and the importance of social science, we created these lesson plans based on research, experience, and student and mentor feedback. For more details on this project, please see wpi.orgsync.com/org/robokids.

These lesson plans can be used by any other workshop, program, club, or classroom for their own use. Teachers and/or leaders should modify the lesson plans as necessary for their own environment. We have noted opportunities for modification, variations, and or expansion in some cases.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, read through the lesson plan. Some of the preparation may require building or acquiring supplies and we generally find it helpful to be able to plan these and not run around last minute on the day of the activity. Mentors should read the explanation of the activity, what the mentors need to know, and helpful questions for them to ask. If they have any questions, these should be clarified before the activity.

Use the explanation as a guideline of how to instruct the students. If there are rules, restrictions, etc. involved we generally find it helpful to display these on a whiteboard, chalkboard, projection screen, etc.so that students can refer to them and not need to ask repetitively.

Unless otherwise specified, students should be split into groups of 2-3 students with 1 mentor per group. In our experience we have found that this is generally the most successful arrangement as larger groups make it difficult for all the students to be involved and hands-on.

Students should then proceed to complete the activity, with the mentors supervising. Mentors should use the questions in the lesson plan as a guide. See Instructions for Mentors.

In general, we do not have a post-activity discussion. Instead we rely on the mentors to do the necessary discussion DURING the activity. You may wish to modify this and have a get together at the end of the activity and have the students compare what they learned during the activity.

Instructions for Mentors

These lesson plans are based off the format of a Robokids activity. Instead of a traditional classroom lecture with one teacher and numerous students, we split students into small groups and assign one mentor per group. Instead of lecturing, mentors facilitate students' learning by guiding them with questions, trying to avoid long explanations whenever possible. Students are asked to try to apply their own knowledge, see how well it works, and then analyze if they were correct or not and draw their own conclusions from there. From this philosophy, we ask our mentors to follow these guidelines:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.

- Tailor to skill level. Multiplying by a decimal can be the same as dividing. Have students solve the same calculation by different methods.
- If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Description of Each Section

Background & Context:

- Length
  - An estimate of how long the activity will take. The first amount is the amount of time we allot to the students to complete the activity.
  - The second includes some buffer time for explanation of activity, distributing materials, and cleaning up at the end.
- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.

Preparation:

- Materials Needed
  - A list of supplies that are needed for the activity.
- Preparation
  - Tasks & setup that need to be completed prior to the activity.

- Notes for Leader
  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- What Mentors Need to Know
  - All leaders and mentors should be briefed before the activity. This section lists what the mentors ought to know in order to help the students, ask good questions, and be able to troubleshoot. Mentors should read this section in advance of the lesson in case they need training or clarification.

Implementation:

- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Suggested questions for the mentors to ask to help guide the students through the activity.
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

How to Use - Short 2

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students. You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing. Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it’s wrong.

Further Descriptions of Some Sections

Prerequisites

- Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.

- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader
  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Common Core Standards 3

Table of Standards and Related Activities

Area	Common Core Standard	Robokids
Math	Make sense of problems in solving them	Programming III: Line Following Programming IV-B: Ultrasonic Programming IV:3 Sensors Mechanical II: Racing Mechanical III: Sumo
	Reason abstractly and quantitatively	Computer Science I: Binary Human Robots I: PB&J Human Robots II: Human Sensors Mechanical II: Racing Mechanical III: Sumo
	Construct viable arguments and critique the reasoning of others	All
	Look for and make use of structure	Programing II: Shapes Programming III: Line Following Programming IV-A: Touch Programming IV-B: Ultrasonic Programming IV:3 Sensors
	Look for and express regularity in repeated reasoning	Computer Science I: Binary Human Robots I: PB&J Human Robots II: Human Sensors Programing II: Shapes Programming III: Line Following Programming IV-A: Touch Programming IV-B: Ultrasonic Programming IV:3 Sensors Mechanical II: Racing

Math Grade 2	Extending understanding of base-ten notation	Math I: Cup Stacking
	Building fluency with addition and subtraction	Math I: Cup Stacking Math II: Million Dollar Project Computer Science I: Binary
	Using standard units of measure	Building I: Paper Skyscrapers Building II: Spaghetti Structures Math II: Million Dollar Project Programming IV-B: Ultrasonic
	Describing and analyzing shapes	Programing II: Shapes
Math Grade 3	Developing understanding of multiplication and division strategies for within 100	Math I: Cup Stacking Math II: Million Dollar Project
	Developing understanding of fractions	Math II: Million Dollar Project Programing II: Shapes Mechanical II: Racing
	Describing and analyzing two-dimensional shapes	Programing II: Shapes
Math Grade 4	Developing understanding and fluency with multi-digit multiplication	Math II: Million Dollar Project
	Developing understanding of fraction equivalence	Programing II: Shapes Mechanical II: Racing
	Understanding that geometric figures can be analyzed and classified based on their properties	Building I: Paper Skyscrapers Building II: Spaghetti Structures Building III: Boats
Math Grade 5	Developing understanding of volume	Building III: Boats
Math Grade 6	Using concepts of ratio and rate to solve problems	Building I: Paper Skyscrapers Building III: Boats
	Developing understanding of statistical thinking	Math I: Cup Stacking

Comprehension and Collaboration Grade 2	Participate in collaborative conversations with diverse partners	All
	Follow agreed-upon rules for discussion (e.g., gaining the floor in respectful ways, listening to others with care, speaking one at a time about the topics and texts under discussion)	All
	Build on other's talk in conversations by linking their comments to the remarks of others	All
	Recount or describe key ideas or details from a text read aloud or information presented orally or through other media	All
	Ask and answer questions about what a speaker says in order to clarify comprehension, gather additional information, or deepen understanding of a topic or issue.	All

<table>
<tr><td rowspan="5">Comprehension and Collaboration Grade 3, 4,5</td><td>Engage effectively in a range of collaborative discussions with diverse partners, building on others' ideas and expressing their own clearly</td><td rowspan="5">Robokids offers easy alternatives to written tutorial information.

Connect previous lessons on sensors with the programming ones, and so on.

Mentors ask "what does this mean?" "how can we apply last lesson to this?"

Easy for teachers to expand on and connect with lessons and use as examples.

Information presented:
orally: mentors
visually: programming guides and code
quantitatively: numbers in code and bock settings</td></tr>
<tr><td>Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion</td></tr>
<tr><td>Ask questions, stay on topic, and link their comments to the remarks of other</td></tr>
<tr><td>Review the key ideas expressed and draw conclusions</td></tr>
<tr><td>Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally</td></tr>
<tr><td>Literacy Grade 2</td><td>Know and use various text features (e.g., captions, bold print, subheadings, glossaries, indexes, electronic menus, icons) to locate key facts or information in a text efficiently</td><td>Scratch, NXT software</td></tr>
<tr><td>Literacy Grade 3</td><td>Determine the meaning of general academic and domain-specific words and phrases</td><td>Terms such as: duration, power, sensor, calibration, circuit, resistor, etc.</td></tr>
<tr><td>Literacy Grade 4</td><td>Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages)</td><td>Scratch
NXT
Forces on Bridges
Electrical Circuits</td></tr>
</table>

Literacy Grade 5	Explain their own ideas and understanding in light of the discussion	Mentors direct student discussion: “What do you want to do? Why?” Students are directed to work with each other rather than with mentor
	Ask and answer questions about information from a speaker, offering appropriate elaboration and detail	As students become more familiar with activities, they should be able to direct more their own learning

Building I 4

This chapter covers a simple building activity. Students are asked construct the tallest possible tower given a limited amount of paper. Can be expanded to include some mathematics.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

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Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students. You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing. Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

Prerequisites

- Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.

- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

- These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.

- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Paper Skyscrapers

Length

Activity time: 30 minutes

Total time: 40 minutes (Includes explanation and clean-up.)

Prerequisites

None

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter..

Common Core Area	Common Core Standard	Robokids Related Task
Math Grade 2	Using standard units of measure	Measure towers in inches, feet, centimeters, meters
Math Grade 4	Understand that geometric figures can be analyzed and classified based on their properties.	Tower is made of shapes - cylinders, prisms, etc.
Math Grade 6	Use concepts of ratio and rate to solve problems	Most efficient use of paper. Paper per inch of height, etc.

Motivation

Engineering means problem-solving

Instructional Objective

- Students should be able to identify properties of successful towers.
- Students should be able to articulate flaws/weaknesses of their tower.

Materials Needed

You will need these materials to run the activity:

- Paper - we recommend standard copy or construction paper
  - Amount can vary depending on how much you have. 10-15 sheets per each group of 2-3 students works well. Another variation is to give them access to unlimited paper.
- Yardstick

- Optional: tape (masking or scotch)

Preparation

These tasks should be completed prior to running the activity:

- Acquire materials needed

Notes for Leader

- Depending on where you're working and if you are allowing the students to use tape, you may allow for forbid them from taping their tower to the ground surface.
- A simple math activity would be to have the students estimate how much paper they used and divide the height by the paper used. What is the most efficient use of paper?

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- Students are allowed to rip the paper

IMPORTANT! Mentors should keep their hands off the towers

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- The goal is to build the tallest possible tower
- It must be freestanding when measured. You can't hold it, it can't be leaning against a wall, etc.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- If paper is flat, how do we make it be tall?
- How can we balance/stack the shapes you've made?
- How do we stop the tower from toppling over?

Building II 5

This chapter covers a building activity that is slightly more challenging than paper skyscrapers due to the materials used. Students are tasked with building the tallest possible structure with spaghetti and marshmallows. A possible extension involving weight support is included.

This chapter includes:

How To Use This Lesson Plan

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Background

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How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing. Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
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- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Spaghetti Structures

Length

Activity time: 40 minutes

Total time: 50 minutes (Includes explanation and clean-up.)

Prerequisites

None

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter

Common Core Area	Common Core Standard	Robokids Related Task
Math Grade 2	Using standard units of measure	Measure structures in inches, feet, centimeters, meters
Math Grade 4	Understand that geometric figures can be analyzed and classified based on their properties.	Structures can consist of cubes, prisms, pyramids, etc.

Motivation

Engineering means problem-solving

Instructional Objective

- Students should be able to identify properties of successful structures.
- Students should be able to articulate flaws/weaknesses of their structures.

Materials Needed

You will need these materials to run the activity:

- Spaghetti
- Mini-Marshmallows
- Cardboard bases, approximately 12”x12”
- Ruler
- Optional: newspaper
- Optional: lightweight flat plate/tray & small weights (marbles, coins, etc.)

Preparation

These tasks should be completed prior to running the activity:

- Acquire materials needed

Notes for Leader

- Depending on where you're working, you may wish to cover the surfaces with newspaper to assist with cleanup. Squashed marshmallows tend to get smeared everywhere.
- If you have a safe storage location, store the towers until the next meeting. The marshmallows will dry and harden. The next meeting, place your lightweight tray on top of the structure, add weights, and see which can hold the most. Discuss.
- Be aware of your student groupings.
  – You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  – Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- Students are allowed to eat the marshmallows or tear them into pieces, but they will not get extra.
- Students may break spaghetti, but they will not get extra.
- Students should try to make a plan BEFORE beginning to build.

IMPORTANT! Mentors should keep their hands off the towers

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- The goal is to build the tallest possible tower
- It must be freestanding when measured. You can't hold it, it can't be leaning against a wall, etc.
- There must be freespace within the tower. It can't simply be a pile of marshmallows with toothpicks stuck inside.
- Optional: If supporting weight at future meeting (see Leader Notes), the top surface needs to be flat enough to hold a tray.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- How do we build a tall structure?
- What prevents a structure from falling over or collapsing?
- Do the marshmallows provide any challenges?
- Does the spaghetti provide any challenges?
- How can we overcome the challenges caused by the spaghetti and marshmallow?
- What's a strong shape?

Building III 6

This chapter covers a hands-on building activity where students construct boats out of duct tape. The goal is to hold as much weight as possible before sinking.

This chapter includes:

How to Use Lesson Plan

Duct Tape Boats

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

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How to Run a Lesson

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Use the explanation as a guideline of how to instruct the students. You may wish to display any specific rules.

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In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

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- Do not ask long, rambling questions that are actually disguised explanations/lectures.
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- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
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Further Descriptions of Some Sections

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- Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.

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- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

- These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.

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- Questions for Mentors to Ask Students
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Duct Tape Boats

Length

Activity time: 40 minutes

Total time: 55 minutes (Includes explanation and clean-up.)

Prerequisites

None

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

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Common Core Area	Common Core Standard	Robokids Related Task
Math Grade 4	Understand that geometric figures can be analyzed and classified based on their properties.	Surface area of boat bottom.
Math Grade 5	Develop understanding of volume	Volume of boats. Water displacement.
Math Grade 6	Use concept of ratio and rate to solve problems.	Ratio of weight to surface area

Motivation

Students like to play with water activities because they are uncommon. The weight-holding can easily become a competition which keeps them engaged. Weight-distribution is critical for many applications - like real boats, rocket ships, or robots.

Instructional Objective

- Students should be able to explain the relationship between the shape & size of their boat and the weight it was able to hold.

Materials Needed

You will need these materials to run the activity:

- Duct Tape (we suggest 1 roll per 5 kids)
- Container at least 5” deep and a mouth with an area of at least 1 sq foot.

  - If container is large, a means of transporting water like a jug or smaller bucket
- Newspapers, towels, or paper towels. LOTS.
- Small weights such as coins, marbles, nuts, and/or bolts

Preparation

These tasks should be completed prior to running the activity:

- Cover area larger than container with newspapers/towels
- Place container in center of covered area and fill with water. Do not fill to the very top. Leave an inch or so for the water level to rise when the boats sink.

Notes for Leader

- Water does tend to get everywhere. Take proper precautions. Carpet can get ruined and tile floors can become highly slippery.
- You may wish to cover the students' workspaces with paper towels as well.
- We also recommend having a designated towel to dry boats after they have been tested.
- If the duct tape gets stuck to itself before being used in construction, it can be replaced by the lead student.
- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- One mentor will act as the official Navy officer. They will add weights to each boat consistently at the same weight, will officially declare when a boat has sunk, and will indicate the amount of weight each boat officially held for record.
- Mentors should work to make sure duct tape and hair do not mix.

- Children should be encouraged to plan a design BEFORE they begin building - duct tape is hard to reuse.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- Each group of 2-3 students will receive 3 strips of duct tape, each the length of the leader's arm - no more!
- Students need to use the duct tape to build a boat that can hold as much weight as possible before sinking.
- Sinking occurs as soon as water comes over the edge into the side of the boat.
- You can change and test your boat as much as you like in the time allotted.
- After every group has made and tested one boat, each group will receive another 2 strips of duct tape to make a second boat.
- Whichever boat holds the most weight in the second round wins.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- What shape do you want your boat to be?
- How can you hold a lot of weight?
- How will you prevent the boat from sinking?
- How are you going to use the duct tape?

  Fold it in half, layer strips, pinch to make corners, fold and tape to make corners, etc.

Math I 7

This chapter covers a basic math activity that has the children sorting and stacking cups basic mathematical principles e.g. multiple of 5, odd numbers, even numbers, tens digits, etc. There are also instructions for a probability game using the cups. The activity is highly modifiable for different mathematics levels.

This chapter includes:

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- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing. Have students solve the same calculation by different methods.
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- Motivation
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  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Numbered Cup Stacking

Length

Activity time: 40 minutes

Total time: 50 minutes (Includes explanation and clean-up.)

Prerequisites

None

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter

Common Core Area	Common Core Standard	Robokids Related Task
Math Grade 2	Extending understanding of base 10 notation	Sort by one's digit; sort by ten's digit
Math Grade 2	Building fluency with addition and subtraction	Adding scores in probability game.
Math Grade 3	Develop understanding of multiplication and division strategies for numbers within 100.	Sort by multiples of 3, sort by numbers divisible by 2, etc.
Math Grade 6	Develop understanding of statistical thinking	Probability game

Motivation

Everyone has a cup - every time you successfully complete a task, you'll get a (jelly bean/M&M/skittle/reese's piece) in your cup. The more tasks you complete correctly, the more candy you get.

Instructional Objective

By the end, students should be able to complete the sorting tasks faster than they started. They should need less help from mentors.

Materials Needed

You will need these materials to run the activity:

- 100 paper dixie cups per every 4 students plus some extras to hold candy

- A sharpie
- Small bulk candy (jelly beans, M&Ms, etc.)
- Paper and writing utensils for each student.

Preparation

These tasks should be completed prior to running the activity:

- Use the sharpie to number each set of cups 1-100 on the bottom of the cups

Notes for Leader

- This is a more directed activity, rather than an exploration-based one. You, or whichever mentor will be leading, should follow the instructions included below in "Explanation of Activity for Students"

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- What a legal pyramid is
- The rules of the probability game (explained below in step 4 of "Explanation of Activity for Students".)

IMPORTANT! The mentors should never touch the cups

Explanation of Activity for Students

The stacking activity should be easy for the children to grasp without written instructions. For the probability game, it is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- Each group will get a set of cups. We'll ask you to stack the cups in different ways. The group that's fastest will get candy.

Stacking:

1. Divide the students into groups of 4 and give each group a set of 100 cups.
2. Explain/ demonstrate a legal 2-dimensional cup pyramid.

   Cups are upsidedown, stacked on top of each other. Each level of the pyramid should consist of a single row of cups in a mostly straight line.
3. Each group of four should use all of the cups to build the tallest cup pyramid possible. Reward the fastest team.

4. Challenge the students to build the tallest pyramid possible using only certain sets of cups. For example “multiples of 2, 3, 5, or 10” Reward the fastest group.
    a. Repeat Step 4 several times, changing the parameters of what cups they can use.

Probability Game:

1. Break each group in half so that the students are now in groups of 2. Split the cups so that each group has either cups 1-50 or 51-100.
2. Challenge each group of two to build pyramid using only certain set of cups. For example “cup containing the numbers 3 or 7”. Reward the fastest group
    a. Repeat Step 7 several times, changing the parameters of what cups they can use.
3. Have each pair of students put all of their cups into a single stack randomly so that the numbers are not in any order.
4. Explain the rules for the probability games:
    a. Each student has a TOTAL score and a score for their current TURN.
    b. The pair of students takes turns holding the stack of cups. The scorer always begins their turn with a TURN score of 0 and whatever TOTAL score they have accumulated in prior turns.
    c. The student holding the stack of cups (HOLDER) asks the other student (SCORER) “Do you want the NEXT cup for me to SHUFFLE, or to END your turn?”
    d. If the scorer wants the NEXT cup, the holder reveals the cup underneath the top cup. Only the ones digit is considered in this game.
        - If the ones digit is a 3 or a 7 the scorer’s TURN score is 0 and their TOTAL score will remain unchanged. Their turn has then ended, and the students switch roles.
        - If the cup directly under the 3 or 7 is also a 3 or a 7 the scorer’s TURN score ***and*** TOTAL score for the entire game are cleared to 0. Their turn has then ended, and the students switch roles.

- If the ones digit is NOT a 3 or 7, then that digit gets added to the scorer's TURN score for their current turn. The holder then repeats the next/shuffle/end question.
- The revealed cup(s) should be placed at the bottom of the stack.

e. If the scorer wants to SHUFFLE, the holder should shuffle the cups in the stack and ask the next/shuffle/end question again.

f. If the scorer wants to END their turn, the sum of points in their TURN score is added to their TOTAL score. (The TURN score will restart at 0 for their next turn.)Their turn has then ended, and the students switch roles.

g. Let the students play several turns so they both get several chances to be scorer and holder.

5. Stop and talk about the probably involved in the games

   a. See "Questions for Mentors to Ask Students"

6. Continue playing the game for several more turns.

Questions for Mentors to Ask Students

For stacking games:

Note: This game should require significantly less assistance/advice than other activities included in these lesson plans. The mentors should focus on social interaction with the students, keeping the teams working together and making sure all the students are involved.

Note: Students should mostly be able to help each other for these games. If the majority of them are struggling severely, mentors should indicate to the activity leader that the sorting parameters need to change to be more age appropriate for the children. At the very minimum, students should be able to sort by 5's, 10's, evens, and odds.

IMPORTANT! Mentors should not put their hands on the cups!

For probability game:

- What's your total score?
- Did you turn over a lot of cups in a row? Or did you end your turn quickly?
- Which strategy is riskier? Why?

- What are the odds of finding a 3 or a 7?

  *In cups numbered 1-10, how many are there? 2. That's 2:10 odds. We can simplify 2:10 to 1:5. What if we want a percent? 2/10=.2 which is 20 percent. Or if we know percentages are out of 100, 10*10=100, so 2*10=20 or 20%.*
- What are the odds of two 3 or 7 cups in a row?

  Multiply:(2/10)(2/10)=4/100 or a 4% chance*

Note: This conversation should take place at the level of the students' understanding. Younger students may not grasp the math but can understand the idea of "riskier" and "more likely" based on their experiences with the game. Older students may be able to grasp more of the mathematical explanations.

Math II 8

This chapter covers a bath based activity which allow student groups to design their own business - provided they budget adequately.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

- These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.

- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Million Dollar Project

Length

Activity time: 90 minutes

Total time: 2 hours (Includes explanation, break, and clean-up.)

Prerequisites

None

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
Math Grade 2	Using standard units of measure	Dollars
Math Grade 2	Building fluency with addition and subtraction	Either sum purchases to total or subtract purchases from amount available.
Math Grade 3	Develop understanding of multiplication and division strategies for numbers within 100	Calculating tax
Math Grade 3	Develop understanding of fractions	Calculating tax
Math Grade 4	Developing understanding and fluency with multi-digit multiplication	Calculating tax

Motivation

Design your own business! You're in charge of an amusement park/etc.!

Instructional Objective

These are sample objectives. They may be modified to fit the grade level of the students. The MASS DESE requires Massachusetts students to begin basic multiplication/division with single numbers by grade 3.

- Students accurately sum two numbers greater than 1,000 by hand.
- Students can accurately write the multiplication or division equation needed to find tax.
- Students can find correct numeric answers to tax equation, decimal place may be in wrong location.
- When students calculate tax, they sum the value with the original price to find the total price.

Materials Needed

You will need these materials to run the activity:

- Print outs from the internet and/or clippings from newspaper & magazine ads. A LOT of them.
  - You should have a minimum of 30-40 images for each group of 2-3 students. The more pictures you have, the more choice the students have, and the more they'll enjoy the activity.
- Scratch paper and writing utensils

Preparation

These tasks should be completed prior to running the activity:

- Choose as many businesses as you anticipate groups.
  - Kids tend to like fun ones like an amusement park, a zoo, a mad scientist laboratory, a rock band, etc.
- Collect pictures and print-outs, at least 30-40 for each business.
  - We suggest storing each set of pictures in its own envelope to keep them separate.
- Write a price for each object on the back of the picture. Make sure the magnitude of the amounts vary.
  - Make sure it is possible for them to sum up to a million dollars with no more than 2/3 of the pictures. Making choices and budgeting helps keep the activity interesting for the students.
  - If you have more advanced students, you could include cents as well. We kept to even dollar amounts.

Notes for Leader

- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Be aware of your student groupings.
  - You may wish to keep the advanced students separate from other students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix advanced students with he rest. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.
- It is critical that mentors are well trained. They will need to keep students on task, make sure that all students are participating, and explain how to solve math problems. They should never just tell the students how to solve a problem, but explain and teach.
- To change difficulty of math, you could include cents and/or require the tax calculation. The tax rate could be 8% instead of 10%.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- How to explain how to add multi-digit numbers.
  - Align the one's digit on the right hand side, NOT the first digit of each number.
  - How to carry the one.
- How to explain how to subtract multi-digit numbers.
  - How to align the numbers
  - How to borrow
- How to find tax
- How to explain how multiply by a fraction/how to multiply by a decimal/how to divide
  - Long division by hand
  - What to do with decimal points

IMPORTANT! Mentors should not actually solve the equations the students need to solve. If they want to demonstrate how to do one of the mathematical tasks listed above, they should make up their own problem as an example, and then ask the student to try again.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- Each group has 1 million dollars to spend. Each group must spend EXACTLY 1 million. To prove this, students will do calculations to keep track of what they buy and how much they spend. Calculating tax is OPTIONAL for bonus.
- At the end of the activity, students will be asked to present the name of their business, the type of business, one item they purchased, how much it cost, and why they chose it.
- Tax is 10%.

Questions for Mentors to Ask Students

- Verify the math level of the students in group. Can they add? subtract? Multiply? Divide? Do they know fractions? Do they know percentages?
- How are you keeping track of your spending?

  Summation of amount spent so far OR subtract purchases from 1 million dollar budget.
- What is tax? How do you calculate it?

  Summation of amount spent so far OR subtract purchases from 1 million dollar budget.

Computer Science I 9

This chapter is based off activities created by Computer Science Unplugged. These activities introduce students to the foundations of computer science - binary and sorting - without using computers.

More information on Computer Science Unplugged can be found at **http://csunplugged.org/**

The specific video we based our activities on can be found at **https://www.youtube.com/watch?v=VpDDPWVn5-Q**

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Binary Bits & Sorting

Length

Activity time: 40-90 minutes (Depends on how many of the parts you choose to do.)

Total time: 1-2 hours (Includes explanation, several rounds of sorting so more students can get a chance, and clean-up.)

Prerequisites

None

Compatible Common Core Standards

This activity has several components that relate to Common Core standards, listed below. Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Reason abstractly and quantitatively	How computers use binary both conceptually and in implementation.
General Math	Look for and express regularity in repeated reasoning	Adding binary digits, repeated patterns in sorting.
Math Grade 2	Building fluency with addition and subtraction	Adding binary bits to find digital number

Motivation

What is computer science? What do computer scientists do? How do computers store and send information?

Instructional Objective

Students should be able to name 1 way that computers keep track of information.

Materials Needed

This lesson is based on "Computer Science Unplugged - The Show", which can be found at this hyperlink https://www.youtube.com/watch?v=VpDDPWVn5-Q

You will need these materials to run the activity:

- Signs labeled 1, 2, 4, 8, 16, 32 on one side
  – for binary counting

- 2 colors of index cards (and tape) or post-it notes
  - for black/white tiles
- [optional] Cake, candles, lighter, knife
- Plastic cup & small objects (e.g. rubber ball)
- Large sheet of paper, sheet, or shower curtain to make sorting floor mat. Tape & construction paper to label floor map.

Preparation

These tasks should be completed prior to running the activity:

- Prepare the signs.
- Make the sorting map.
- [Optional] Bake or purchase cake.

Notes for Leader

- This can be a longer activity. If you do run the longer version, we recommend a snack break or other pause about halfway through.
- This is an activity where we worked with all the students together rather than splitting them up into groups.
- Have the mentors rotate being leader and assistant so they all get a chance to be in front. Make sure they watch the video first and are prepared!

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- Mentors should all watch the video!
- How binary works
- How sorting works
- Examples of how computers can use binary & sorting.

Explanation of Activity for Students

Reference the “Computer Science Unplugged - The Show”, video at https://www.youtube.com/watch?v=VpDDPWVn5-Q

Questions for Mentors to Ask Students

Reference the “Computer Science Unplugged - The Show”, video at https://www.youtube.com/watch?v=VpDDPWVn5-Q

Human Robots I 10

This chapter introduces the idea of code as a series of very literal instructions. They will attempt to instruct a “robot” (played by a mentor) how to make a peanut butter & jelly. The misunderstandings by the robot will help them learn that robots are not intuitive and cannot guess what the code intends to mean.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

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Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Peanut Butter & Jelly

Length

Activity time: 45 minutes

Total time: 1hour (Includes explanation and clean-up.)

Prerequisites

None

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Reason abstractly and quantitatively	Explain the robot's point of view of making the PB&J. Specific commands.
General Math	Look for and express regularity in repeated reasoning	Learning from other students' commands; learn patterns of effective commands.

Motivation

Students are used to intuitively receiving commands. Instructing a "robot" how to make a PB&J will help them understand that code is extremely literal and needs very precise details.

Instructional Objective

Students should learn to give commands that have precise information such as amount, time, left/right, direction, strength, etc.

Materials Needed

You will need these materials to run the activity:

- Loaf of Bread
- Jar of Peanut Butter
- Jar of Jelly
- Knife
- Spoon
- Paper plates

- LOTS of paper towels

Preparation

These tasks should be completed prior to running the activity:

- Cover a table in paper towels. Make sure table is visible to all students.
- Place all other materials on the table.

Notes for Leader

- If any student has peanut or other allergies, substitute with other sandwich toppings or condiments as desired.
- The mentor who will be playing the robot needs to understand exactly how literal they are supposed to be. Actions should be exaggerated to make a point and entertain.
  - For example, if told to “Open the bag” of bread, they should grab the bag and rip it open from the side so that everything goes flying.
  - “Open the jar” requires the commands “hold the jar still with one hand” and “WHILE holding the jar still, twist the lid COUNTERCLOCKWISE with your OTHER hand”
  - If told to “put____down” without a location specified, the robot should drop the object without moving their hand, even if it means the object will fall to the floor.(Although you may place glass jars down safety.)
- The activity continues until a PB&J sandwich is completed or you run out of time.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

Note: This activity requires less teaching on the mentors’ parts; they can focus more on social interaction with the students.

- One mentor will need to play the robot. The robot will be extremely literal/
- Another mentor should be the director - calling on the students in turn, repeating the instructions loudly so that both robot and the other students can hear.
- The other mentors should distribute themselves amongst the students and help the students to plan their commands.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- [Mentor Name] is going to be a robot. You have to tell them how to make a peanut butter & jelly sandwich. They have a loaf of bread inside a bag, a jar of peanut butter, a jar of jelly, a spoon, and knife, and some paper plates. We'll go around and each student will get command the robot to do ONE action. We'll keep going around until the robot has a finished sandwich on a plate. So, what is the first thing the robot needs to do?

Questions for Mentors to Ask Students

- Well, if you tell the robot to do_____, what do you think will happen?
  - *Have the student pretend to be a robot and mime it out.*

IMPORTANT! Don't tell the student their command is "wrong" or "won't work". Let them give an incomplete command and watch how the robot misinterprets it. They will learn more this way. If the student has made numerous bad commands and the rest of the students are getting frustrated or angry, stay positive and encourage them. Give them a sample command and let them pretend to be a robot themselves at their desk.

- What happened when [previous student] told the robot to [follow a similar command]?

Human Robots II 11

This chapter covers an activity that builds upon Human Robots I by introducing the use of sensors. Rather than assuming the human robot can intuitively figure out location and distance, the idea of sensors to measure and detect adds another element to include in commands.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Human Sensors

Length

Activity time: 40 minutes

Total time: 50 minutes (Includes explanation, races, and clean-up.)

Prerequisites

None

Optional: Introduction to the idea that programming is extremely literal. We recommend Human Robots I, Peanut Butter & Jelly.

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Reason abstractly and quantitatively	Explain the robot's point of view. Specific commands.
General Math	Look for and express regularity in repeated reasoning	Learning from other students' commands; learn patterns of effective commands.

Motivation

Students are used to intuitively receiving commands. Instructing a "robot" how to make a PB&J will help them understand that code is extremely literal and needs very precise details.

Instructional Objective

- Students should be able to match sensors and data types together
- Students should be able to explain how the robots use the sensors on a high-level. ("To see" or "to feel")

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit with sensors
- Tables
- Black electrical tape

Preparation

These tasks should be completed prior to running the activity:

- Mark a path out with tape
- Outline a path with the tables

Notes for Leader

- The mentor who will be playing the robot needs to understand exactly how literal they are supposed to be. Actions should be exaggerated to make a point and entertain.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

Note: This activity requires less teaching on the mentors' parts; they can focus more on social interaction with the students.

- One mentor will need to play the robot. The robot will be extremely literal.
- Another mentor should be the director - calling on the students in turn, repeating the instructions loudly so that both robot and the other students can hear.
- The other mentors should distribute themselves amongst the students and help the students to plan their commands.
- Each sensor, what data is takes in, and how it can be used.

Explanation of Activity for Students

It is best if you post the types of sensors and what kind of data they can read/see in a place the students can easily see. This will help keep them on task and help minimize confusion.

- [Mentor Name] is going to be a robot. You have to tell them how to traverse a maze. They have a BUMP sensor held in front of them so they can tell when they run into a wall. We'll go around and each student will get command the robot to do ONE action. We'll keep going around until the robot gets out of the maze. So, what is the first thing the robot needs to do?
- [Mentor Name] is going to be a robot. They have an ULTRASONIC RANGE-FINDER sensor held in front of them so they tell HOW CLOSE they are to a wall.
- They have a LIGHT sensor held in front of them so they tell if they are currently STANDING ON or OFF a tape line.

Questions for Mentors to Ask Students

- Well, if you tell the robot to do_____, what do you think will happen?
  - *Have the student pretend to be a robot and mime it out.*

Don’t tell the student their command is “wrong” or “won’t work”. Let them give an incomplete command and watch how the robot misinterprets it. They will learn more this way. If the student has made numerous bad commands and the rest of the students are getting frustrated or angry, stay positive and encourage them. Give them a sample command and let them pretend to be a robot themselves at their desk.

What happened when [previous student] told the robot to [follow a similar command]?

Introduction to LEGO Robots 12

This chapter covers resources for learning more about LEGO(R) Mindstorms robots and the NXT-G programming software. The system is easily learned. For mentors with any prior programming experience, they should be able to pick up the software by simple trial-and-error and experimentation. This chapter also includes links to instructions or building simple base robots and links for more activity ideas.

This chapter includes:

Mindstorms Introduction

Main Resource

Mindstorms(R) Robots are made by LEGO. Their main webpage has links to activities, technical support, and additional supplies.

- http://mindstorms.lego.com/en-us/default.aspx

Kit

There are multiple versions of LEGO NXT-based robots. Our lesson plans were designed using LEGO MINDSTORMS Education NXT Base Set (9797) using NXT-G software, but they should be broadly applicable to the other kits as well.

Base Bot Drivetrain

There are multiple resources online that have instructions for a simple basebot that can drive around. Instructions are also usually included with the kits.

- Online versions include the Express Bot found here: http://www.nxtprograms.com/9797/express-bot/index.html

Building Resources

This has the express bot instructions, and instructions for another attachments like arms and sensors. Each set of build instructions includes specific programming instructions.

- http://www.nxtprograms.com/9797/express-bot/steps.html

General NXT Programming Resources

If you have any prior programming experience, NXT-G software tends to be very easy to pick up just by experimentation with the programming. However, even those with no programming knowledge can learn the necessary basics fairly quickly. We recommend using the following resources.

This website is the same as above, but sorted by programming tasks & complexity rather than by building tasks.

- http://www.nxtprograms.com/projects2.html#ProjectsByProgram

This website includes video walkthroughs explaining different programming concepts and blocks used in the NXT software. It also includes programming activities to use the basic concepts.

- http://www.stemcentric.com/nxt-tutorial/

Mechanical I 13

This chapter covers a simple non-structured activity that introduces students to the LEGO(R) Mindstorms kits, and/or allows them some freedom to build their own creations without any sort of pressure or restrictions.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

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Each lesson plan is organized into multiple sections.

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Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

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How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
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Kit Exploration

Length

Activity time: 40-90 minutes

Total time: 1-2 hours (Includes explanation and clean-up.)

Prerequisites

This activity is generally intended for students who have little to no experience with LEGO Mindstorms kits

Compatible Common Core Standards

This activity is compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter

Motivation

Playing with LEGOs is fun. However, the Mindstorm kits don't look like normal LEGOs and students can be intimidated by the idea that the pieces are meant for building robots. This activity should get the students playing and experimenting with the pieces so they are more comfortable and familiar with them for future activities. Alternatively, it can be just a fun activity for students who are familiar with the kits but need a break from being told exactly what to do.

Instructional Objective

- Students should be more comfortable and confident in handling the LEGO pieces.
- Students should be able to ask questions as necessary, make an attempt at building things.

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit(s)

Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

Preparation

These tasks should be completed prior to running the activity:

- See Notes for Leader below.

Notes for Leader

- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Optional: print out some building guides ahead of time. Give students the opportunity to follow them if they wish.

- The success of this activity can vary wildly depending on the students. Some will be lost without building guides to follow, others will struggle with the building guides and not complete anything within 2 hours. Our best recommendation is to make sure there is 1 mentor per every 2-3 students.
- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- That LEGOs are awesome and there's no such thing as building things "wrong".

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- You have kits with LEGO pieces - build whatever you want.
- Optional: We have building guides if you want to try to follow them. Otherwise make up your own ideas. Have fun.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- What do you want to build?
- How can we connect these pieces?
- What does this piece do?
- How can we make a ramp? An arm? A truck?

In the case of a building guide:

- How does this picture look different from the previous one?
- What is our structure missing?
- What do we need to do next?

- What do we need to do to make our robot look like the one in the picture?

Programming II 14

This chapter introduces programming using NXT-G software. Short programs are downloaded to LEGO Mindstorms robots that instruct the robots to drive in paths that create geometric shapes. Students will learn the fundamental MOVE and LOOP programming blocks in the NXT-G software.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

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How to Run a Lesson

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Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
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  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Drawing Shapes

Length

Activity time: 1.5 hours

Total time: 2 hours (Includes explanation, break, and clean-up.)

Prerequisites

Some introduction to the concept of programming. We recommend the activity included in Chapter 10, Human Robots I.

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Look for and make use of structure	Programming: loops, right/straight/left motion blocks
General Math	Look for and express regularity in repeated reasoning	Programming: loops, right/straight/left motion blocks
Math Grade 2	Describing and Analyzing Shapes	What commands make a specific shape
Math Grade 3	Developing understanding of fractions	90° = (1/2)(180°)
Math Grade 3	Describing and analyzing two-dimensional shapes	What commands make a specific shape?
Math Grade 4	Developing understanding of fraction equivalence	If 2 revolutions cause the robot to turn 180 degrees, 1 revolution should make it turn 90.
Math Grade 4	Understanding that geometric figures can be analyzed and classified based on their properties	Difference between square, rectangle, parallelogram, triangle, etc.

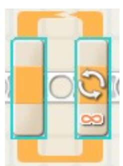
Motivation

Programming can be very abstract when it is buried inside the computer. By programming a robot to follow a very literal series of commands and tracing the resulting path, students gain an understanding of basic programming concepts. They also learn how to use the NXT-G software.

Instructional Objective

Students should be able to identify a MOVE block

Students should be able to identify a LOOP block



Students should be able to explain the difference between the robot moving for 1 revolution, 1 degree, or 1 second.

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit(s)

Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

- LEGO NXT-G software
- Laptops/computers
- Large white board (non-mounted), and dry erase markers
  OR
- Large roll of white paper, non-carpeted floor area, masking tape, and markers

Preparation

These tasks should be completed prior to running the activity:

- NXT-G software must be installed on computers or laptops
- Robots should be built. Drivetrain should have two powered wheels.
- Attach whiteboard markers to LEGO pieces to create an attachment that can quickly be snapped onto and off of the robot base. Tip of the marker must be able to touch ground when cap is removed.
- Arrange the room so that the white board or white paper is lying flat on the floor. In the case of paper, make sure it is taped down securely. It should be accessible and not inhibit movement about the room.

Notes for Leader

- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Depending on where the markers are mounted on the robot, they may draw arcs, points, or other deviations from a perfect 90-degree corner. It is your choice if these are allowed as part of an acceptable shape, or if students must figure out how to overcome them.
- Students should be able to manage 2-3 shapes within the allotted time.
- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- How to create a new program in NXT-G and name it
- How to use blocks in the NXT-G software to create a basic program
- Where to find MOVE and LOOP blocks in the NXT-G software
- How to use the MOVE block to drive straight, turn left, and turn right

- How to change the duration of a MOVE block
- How to change the controlling parameter of the LOOP block, especially the COUNT option.
- How to DOWNLOAD a program to the NXT-G robot
- How to select and run a program on the NXT-G brain
- What will be counted as a valid shape (see “Notes for Leader” on page 14-7 regarding corners)

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- You will be programming the robots to trace various shapes. Each robot comes with a whiteboard marker. When you think you have a working program, download it to the robot, bring the robot to the mentor at the whiteboard. They will attach a marker to the robot and then you can run your program. Watch what shape your robot draws. The mentor will determine if your shape is accurate enough to move on to the next one.
- These are the shapes your robot should draw:
  - Square
  - Rectangle
  - Triangle
  - Circle
  - Free choice - must be a regular polygonal shape (i.e. pentagon, hexagon, star)

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- What do you remember about the PB&J activity? What problems were there? How did you solve them then?
  - *Very literal - "robot" had to be told EXACTLY what to do.*
- How can we tell the robot to draw a square?
- What are the parts of a square?
  - *4 straight sides*
  - *4 (or 3) turns*
- What kinds of turns? What direction are they in?

IMPORTANT! If the students have a hard time grasping the idea that all the turns need to be in the same direction, or that all of the sides are a "drive forward" command (as opposed to a "drive backwards" or "drive left" command) have the students stand up and pretend to be the robot. If they step forward, turn left, step forward, turn right, are they making a square?

- What makes a square different than a rectangle? A parallelogram?
  - *The sides are all the same length.*
  - *The corners are all 90 degrees / The sides are all perpendicular to each other.*

- How does the robot know to turn or move straight?
  - *MOVE block*
  - *STEERING slider bar*
- How does the robot know how long to make each side?
- How does the robot know how much to turn?
  - *MOVE blocks*
  - *DURATION measure & unit*

IMPORTANT! Explain the difference between rotations, degrees, and seconds, but let the students experiment by trial and error which one is the best for producing the corner they want.

- Is there a pattern in our commands? Are we repeating anything?
  - *Pairs of drive straight & turn commands*

Note: This is a good opportunity for the mentor to explain the idea of a LOOP - it will repeat the commands inside. We can determine how many times it repeats the commands with the COUNT option.

- How many times does our pattern repeat for a square? A Triangle?
- Is there a pattern we can use inside a loop for a rectangle?
  - *The four-block chain of straight, turn, straight, turn where the two straight commands have different durations.*
- Does our circle need a loop?
  - *The DURATION inside the MOVE block can be unlimited*

    AND/OR
  - *The LOOP can be forever*

    AND/OR
  - *The LOOP can use time or count options to draw multiple circles on top of each other.*

Programming III 15

This chapter introduces programming using NXT-G software with a light sensor. The Robot Educator Guide will be used as a basis for learning new command blocks. Students will learn the SWITCH STATEMENT programming block in the NXT-G software.

This chapter includes:

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- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Line Following

Length

Activity time: 1.5 hours

Total time: 2 hours (Includes explanation, break, and clean-up.)

Prerequisites

Basic programming skills. We recommend Chapter 10, Programming II.

OPTIONAL: Knowledge of what purpose sensors serve. We recommend Chapter 8, Human Sensors.

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

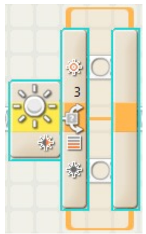
Common Core Area	Common Core Standard	Robokids Related Task
General Math	Make sense of problems by solving them.	Figuring out how to program a robot to traverse a maze
General Math	Look for and make use of structure	Programming: loops, switch statements
General Math	Look for and express regularity in repeated reasoning	Programming: loops, switch statements

Motivation

Robots start as deaf, blind, and isolated. We can add sensors to the robot that imitate our own senses. A light sensor can be used to detect the difference between light and dark. Also, how does a robot make decisions between multiple options? We can use a switch statement to enable the robot to react to different situations.

Instructional Objective

Students should be able to identify a light sensor SWITCH STATEMENT block



Students should be able to explain the logic the switch statement uses.*It checks the light sensor, if darker than value do this, if lighter than value do other action.*

Students should be able to calibrate light sensor to threshold value.

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit(s)

Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

- LEGO NXT-G software
- Laptops/computers
- Large white board (non-mounted), and black electrical tape
  OR
- Large roll of white paper, non-carpeted floor area, masking tape, and black electrical tape

Preparation

These tasks should be completed prior to running the activity:

- NXT-G software must be installed on computers or laptops
- Robots should be built. Drivetrain should have two powered wheels. Light sensor should be attached.
- Arrange the room so that the white board or white paper is lying flat on the floor. In the case of paper, make sure it is taped down securely. It should be accessible and not inhibit movement about the room.
- Using the black electrical tape on the whiteboard or paper, mark an irregular continuous track that meets at both ends and does not cross over itself. Use rounded curves, not sharp angles.

Notes for Leader

- This activity is based on the Robot Educator Common Pallet Guide 17 Follow a Line that is included in the NXT-G software.

- Mentors need to make sure students understand the code and are not just copying blindly from the Robot Educator Guide.
- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.
- If students are finishing quicker than expected, use the following options to extend the activity:
  - Have a race - which robot can follow a lap of the track the fastest? (If you don't have a stopwatch, have them program time loops of the same duration, rather than forever loops.)
  - Add random strips of electrical tape inside the track. Using Robot Educator Guides 16 Detect a Dark Line and 17 Line Following as guides, what behaviors can they program their robot to have?
  - Add a second light sensor to the robot. Can they program it to follow the track while "straddling" the line?

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- Familiarity with creating, naming, and downloading NXT-G programs.
- How to open, find, and navigate through the Robot Educator Guides.
- Familiarity with MOVE and LOOP blocks, and their corresponding menu options.
- That MOVE blocks can be used to control only 1 wheel (motor port), rather than both (the default in Chapter 10, Programming II).
- How to change POWER and the STEERING radius on MOVE blocks.
- How a FOREVER loop is different than a COUNT loop.

- Where to find the SWITCH STATEMENT block in the NXT-G software.
- How to make sure the port number selected for the SWITCH statement is the same as where the light sensor is plugged in.
- The logic behind using the UNLIMITED option on a motion block and using a sensor to control when the robot obeys the next command.
- How to calibrate the light sensor using the NXT-G brain.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- You will be programming the robots to follow this track using a light sensor. The light sensor converts how much light it sees into a numerical value. We can program the robot to do different actions based on if it sees a numerical value greater than or lesser than some threshold value.
  - How fast can you make your robot follow the track?
  - Are higher numerical values “light” or “dark”?
  - Make sure you understand how the switch statement works.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- How can the robot tell the difference between the black line and the white board?
  - *The light sensor will see less light on the line. / The black line will look darker.*
- How can we make the robot do different things if it sees light or if it sees dark?

Note: This is a good opportunity to explain the idea of a SWITCH STATEMENT. For a light sensor it will check if the sensor sees lighter or darker than a given value. Each of those cases has a series of motions it will follow.

- How can the robot follow the line?
  - *It can “wiggle” or “zigzag” so that it follows the line while still moving forward. It may help the kids to watch the Challenge Brief video included in the Robot Educator Guide.*
- What does the robot need to do when it sees the black line?
  - *Wiggle one direction.*

- What does the robot need to do when it sees the whiteboard?
  - *Wiggle the opposite direction.*
- How did we make it turn before? Did it go forward or turn almost on the spot?

IMPORTANT! Let the students experiment with trial and error. The Robot Educator Guide suggests only powering one wheel at a time to create the wiggle forward motion. It can also be achieved by changing the steering slider so that it is not at either extreme or dead center, causing the robot to drive in an arc.

- How does the robot know how much to turn?
- Can we use the duration on the MOVE block?
  - *No, otherwise we are ignoring the sensor. We can change how quickly or sharply the robot turns by using the STEERING and POWER options in the MOVE block menu.*
- Will a switch statement repeat?
  - *No. It will only check the light sensor once.*

IMPORTANT! Let the students try running the code without the forever loop surround the switch statement. Depending on if they start it on the black line or if they start it on the whiteboard it should either always drive straight or always turn, regardless of the line.

- How can we make the robot keep following the line forever?
- Can we use a loop?
  - *A FOREVER loop will make the robot follow the line indefinitely. A time loop will make the robot follow the line for a given number of seconds.*

Programming IV-A 16

This chapter introduces programming non-regular shapes by introducing a maze. The students will program the robot to traverse the maze by using feedback from a LEGO touch sensor.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Touch Sensor

Length

Activity time: 1.5 hours

Total time: 2 hours (Includes explanation, break, and clean-up.)

Prerequisites

Basic programming skills. We recommend Chapter 14, Programming II.

Knowledge of sensors. We recommend Chapter 11, Programming III and/or Chapter 8, Human Sensors

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Look for and make use of structure	Programming: wait blocks
General Math	Look for and express regularity in repeated reasoning	Programming: motion blocks, loops, wait blocks

Motivation

Robots start as deaf, blind, and isolated. We can add sensors to the robot that imitate our own senses. A touch sensor can identify when the robot runs into something. We can use this to navigate a maze. Sensors allow us to be more accurate than trying to “dead reckon” or predict exactly what the environment in like.

Instructional Objective

Students should be able to identify a touch sensor WAIT block

Students should be able to explain the logic the wait statement uses: *The robot will remain in its previous state until the touch sensor is pressed.*

Optional: If students completed Chapter 11, Programming III with the SWITCH statements, students should be able to explain the difference between the SWITCH and WAIT blocks: *The switch has two states, and an action for each state. The wait block does not have any action, it simply stalls the program until whatever its waiting for happens.*

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit(s)

Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

- LEGO NXT-G software
- Laptops/computers
- Lots of cardboard boxes
  - Or other method of making walls with a minimum height of about 6”.
- Tape and/or weights

Preparation

These tasks should be completed prior to running the activity:

- NXT-G software must be installed on computers or laptops
- Robots should be built. Drivetrain should have two powered wheels. touch sensor should be attached.
- Use the boxes to outline a path. Path should have at least 1 left turn and 1 right turn. Straight portions should be of varying length. Path can either have distinct start and end locations, or be a connected loop.

- Either tape the boxes down or put weights in them so the robot can’t push them across the floor.

Notes for Leader

- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.
- If you are short on boxes, it is possible for you to create a path where instead of fully lining both sides of the path, you simply place boxes where the robots should bump and turn. However, the NXT robots frequently do not drive perfectly straight and we find it helpful to have the full lined path to keep the robots relatively on track.
- Any activity where the robot is asked to turn is an opportunity to discuss fractions, degrees, and/or conversion between units.
  - 1 revolution = 360 degree turn of the wheel
  - If the robot is U-turning, that is twice the turn amount needed, i.e. 90 degrees is half of the current turn amount. Theoretically, to turn half the distance we should half the duration.

Note: This can often result in a lesson how theory and practice are not always identical in engineering.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- Familiarity with creating, naming, and downloading NXT-G programs.
- Familiarity with MOVE blocks and their menu options.
  - How the power option can be used to make the robot turn or drive slower which MAY help making the robot’s motion more precise or accurate.
- How to choose the correct type of WAIT block.

- How to use the menu options for the WAIT block.
- How the prior code block interacts with the WAIT block.
  - Differences between having an unlimited duration block vs. having a specified duration block prior to the WAIT block.
- How to verify the code references the correct port number where the sensor is connected.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- You will be programming your robot to travel through this maze. The touch sensor can tell when the robot has run into a wall and needs to turn.
  - Make sure to clarify where the start and end are / what the direction of travel is.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- What are the steps the robot needs to follow to get through the maze?

IMPORTANT! It may help the students to code and test in stages. Code and test drive straight until bumped, then stop. Test until works as desired. Then add a single turn. Test until it works properly. Add the next drive straight, bump, and turn block.

- How long do we want the robot to drive forward?
  - *Continuously until it's hit a wall.*
- How does the robot know it has hit the wall?
- Is the bump sensor pressed, released, or bumped?
  - *Pressed*
- What direction does the robot need to turn for the first corner? The second corner? Etc.

Note: If students have difficulty determining the robot's orientation within the path, have them stand next to the maze and act it out as if they are the robot.

- How do you tell the robot how far to turn?

- Let the students experiment via trial and error the different duration options (seconds, degrees, revolutions) to control their turns.

Note: If students completed Chapter 10, Programming II ask them to recall how they made the robots draw corners for their shapes.

IMPORTANT! Depending on the configuration of the robot, it may be necessary for the robots to back up slightly after hitting the wall and before turning.

Programming IV-B 17

This chapter introduces programming non-regular shapes by introducing a maze. The chapter introduces the LEGO Ultrasonic Range Finding sensor. It is based on the Robot Educator Guide included in the NXT-G software.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Ultrasonic Range Finder Sensor

Length

Activity time: 25 minutes

Total time: 30 minutes (Includes explanation and clean-up.)

Prerequisites

Basic programming skills. We recommend Chapter 10, Programming II.

Knowledge of sensors. We recommend Chapter 11, Programming III and/or Chapter 8, Human Sensors

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Make sense of problems by solving them.	Figuring out how to program a robot to traverse a maze
General Math	Look for and make use of structure	Programming: loops, switch statements
General Math	Look for and express regularity in repeated reasoning	Programming: loops, switch statements
Math Grade 2	Using standard units of measure	Ultrasonic sensor can use inches or centimeters

Motivation

Sometimes we don’t want our robots to run smack into walls. You don’t use your hands to feel every wall to know when to turn. There’s usually not lines on the floor for you to follow. So how does a robot cope in an environement like that? They can use an ULTRASONIC RANGE sensor which works like bats’ echolocation.

Instructional Objective

Students should be able to identify that the ULTRASONIC RANGE sensor is based on the variable of distance.

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit(s)

Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

- LEGO NXT-G software
- Laptops/computers

Preparation

These tasks should be completed prior to running the activity:

- NXT-G software must be installed on computers or laptops
- Robots should be built. Drivetrain should have two powered wheels. Ultra Sonic sensor should be attached.

Notes for Leader

- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Be aware of your student groupings.
  – You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  – Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.
- This activity is based on the Robot Educator Common Pallet Guide 14 Detect Distance that is included in the NXT-G software.
- Mentors need to make sure students understand the code and are not just copying blindly from the Robot Educator Guide.

Note: This lesson is an excellent tie-in to comparing standard inches to metric centimeters.

IMPORTANT! This is a very short activity that simply gets the sensors working. The activity may be expanded by following the maze instructions from Chapter 16, Programming IV-A and substituting the ULTRASONIC sensor for the TOUCH sensor.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- Familiarity with creating, naming, and downloading NXT-G programs.
- How to open, find, and navigate through the Robot Educator Guides.
- Familiarity with MOVE block and its corresponding menu options.
- How to choose the correct type of WAIT block.
- How to use the menu options for the WAIT block.
- How the prior code block interacts with the WAIT block.
  - Differences between having an unlimited duration block vs. having a specified duration block prior to the WAIT block.
- How to verify the code references the correct port number where the sensor is connected.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- You will be using the ultrasonic sensor to prevent the robot from running into walls. The RANGE sensor sends out a wave which bounces off the wall and returns to the sensor. If the wall is far away, it has to cover more distance, meaning it takes longer to return. The robot calculates how far away the wall is based on how long the wave takes to return.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- What is the difference between inches and centimeters? How far do you think 5 inches is? How far is 5 centimeters?
- What happens if we give the first block a duration instead of being unlimited?
- How close to the wall can you program the robot to stop?
- What happens if we change the power setting on the move block?
  - *The robot should be able to stop closer to the wall. This is because there is a time delay for the robot to send the signal, receive it back, and figure out what to do based on the information it receives.*
- What behaviors can you program the robot to do if you change the less than/greater than distance option?

IMPORTANT! Let the students experiment with trial and error.

Programming IV 18

This chapter covers a capstone programming project. Students utilize the touch, light, and ultrasonic range-finder sensors to traverse a maze with no dead-reckoning.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

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Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it’s wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Maze with 3 Sensors

Length

Activity time: 90 minutes

Total time: 2 hours (Includes explanation and clean-up.)

Prerequisites

Basic programming skills. We recommend Chapter 10, Programming II.

Knowledge of light sensor, touch sensor, and ultrasonic range-finding sensor. We recommend Chapter 15, Programming III, Chapter 16, Programming IV-A, and Chapter 17, Programming IV-B.

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Make sense of problems by solving them.	Figuring out how to program a robot to traverse a maze
General Math	Look for and make use of structure	Programming: loops, wait blocks, switch statements
General Math	Look for and express regularity in repeated reasoning	Programming: loops, switch statements

Motivation

In every activity we've done so far [assuming the prerequisite activities] we've had to guess some variables. How long do we want the robot to turn to make a corner? Does the robot need to turn left or right? By combining sensors we can program the robot to work in a maze of any shape.

Instructional Objective

Students should be able to talk through their program block and block and accurately explain what the effect of each block / what each block does in terms of the robot's motions or thinking process.

Materials Needed

You will need these materials to run the activity:

- LEGO(R) Mindstorms robot kit(s)

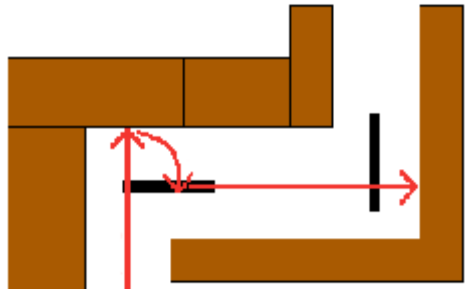
Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

- LEGO NXT-G software
- Laptops/computers
- LOTS of cardboard boxes and masking tape or weights
- White board OR white paper and a hard flooring surface
- Black electrical tape
- Scratch paper and pencils

Preparation

These tasks should be completed prior to running the activity:

- NXT-G software must be installed on computers or laptops
- Robots should be built. Drivetrain should have two powered wheels. The ULTRASONIC range-finding sensor should be attached to one side of the robot, looking to the side not forwards. The TOUCH and LIGHT sensors should be installed on the front.
- Put your whiteboard on the ground, or cover a large area in white paper.
- Use the cardboard boxes to outline a path on the white area. The path can have turns of any angle. It can either connect to form a loop or have a distinct start and end. Make sure that the path is wide enough for the robot to turn at the corners. Tape or weight down the boxes so that they won't move if the robot runs into them.
- Use the electrical tape to lay out black lines that are perpendicular to the robot's approach and parallel to its departure.Reference the illustration below. The red arrow shows the robot running into the wall, turning until it sees the black line, and then traveling forwards again until it hits another wall.



Notes for Leader

- This activity is complicated and contains many parts. You should have a 5-10 minute prep session with the mentors before the activity, to make sure that everyone is clear on what needs to happen.
- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.
- It may help the students to use the scratch paper to think through what the robot needs to do and begin converting that into what code blocks will be needed. For example, run straight until hit a wall needs a move block and a wait block.
- If you have time, after the students have their code working, rearrange the maze to follow a different path and test if the robots can still make it through. Or if you have enough supplies, build a second maze in case the groups make progress at different speeds.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- Familiarity with creating, naming, and downloading NXT-G programs.

- How to open, find, and navigate through the Robot Educator Guides.
- Familiarity with MOVE, WAIT, SWITCH, and LOOP blocks and their corresponding menu options.
- How to find and use the Robot Educator Guides as references for programming each of the sensors.

IMPORTANT! If the LIGHT sensor has a hard time catching the line, decrease the power of the turning MOVE block so that the robot will turn more slowly.

IMPORTANT! If the robot is too crooked when it sees the black line and drive diagonally into the wall, move the black tape line closer to the bumped wall, or program the robots to back up slightly before turning.

- How to verify the code references the correct port number where the sensor is connected.
- How to calibrate the light sensor.
- The sequence of events the program should approximately follow in order to traverse the maze.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- Your robot will traverse the maze using the sensors entirely.
- First it needs to go forward until it hits a wall.
- Then it needs to decide which way to turn. The range sensor is on one side of the robot. If it sees a wall close to the robot, does the robot want to turn in that direction?
- Then your robot will turn. How far does it need to turn? There are black lines on the ground and your robot has a light sensor that can detect light vs. dark. You should be able to turn until your robot sees the line.
- Then the robot can drive straight again until it runs into another wall and needs to use the same process.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

Note: Asking students to write down steps may help them think through the code.

Note: We've found that it helps the students feel less frustrated if they can make incremental progress. Start by getting the robot to drive forward, bump the wall, then stop. Then get the ultrasonic to tell the robot which way to turn. Then implement the light sensor for line detection. Then fine tune the code until the robot can make it through the entire maze.

- What are the steps the robot needs to take?
- How do we tell the robot to move straight?
- How does the robot check to see if it's bumped into a wall?
- What side is the sensor on? How does it know if there's a wall there? How far away do you think the robot could be from the wall?
- If the ultrasonic sees a wall, what way should the robot turn?
- If the ultrasonic doesn't see a wall, what way should the robot turn?
- How does the robot handle two possibilities? How do we tell the robot which way to turn, based on if we see a wall or not?
- How do we actually tell the robot to turn?
- What happens after the robot needs to start turning?
- How does the robot know when to stop turning?
- How does the robot see the dark line?
- What code blocks do we need to look for the line while turning and then do something else after it sees the line?
- What happens next?
- Is there any easy way for the robot to repeat these steps?
- How many times does it need to repeat them?
  - *Number of corners for a maze with distinct start/end + a go forward outside of the loop for the end*
  - *Infinitely for a complete loop path.*

Mechanical II 19

This chapter covers an application of gears and gear ratios. Children experiment with gear ratios to create the fastest racing bot. This activity does not cover how to teach gear ratios. It can either be used as an introduction allowing children to discover by trial and error or as an application of gears after an earlier gear activity.

This chapter includes:

How to Use Lesson Plan:

Racing Bots:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students.You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Racing Bots

Length

Activity time: 40 minutes

Total time: 50 minutes (Includes explanation, races, and clean-up.)

Prerequisites

Knowledge of gear ratios.

- Which direction individual gears in a geartrain will spin
- Change in speed big to small and small to big
- Lack of change in speed if different size gears are on the same axle.

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Make sense of problems in solving them	How gear ratios relate to the speed and performance of robot.
General Math	Reason abstractly and quantitatively	"Big" and "small" gear logic vs. solving out math to find speeds.
General Math	Look for and express regularity in repeated reasoning	How radius relates to velocity.
Math Grade 3	Develop understanding of fractions	Gear ratios
Math Grade 4	Develop understanding of fraction equivalence	Angular velocity to linear velocity
Math Grade 6	Use concepts of ratio and rate to solve problems.	Gear ratios change speed.

Motivation

Speed is awesome. Changing the gears on your robot can make it drive faster. Win the race.

Instructional Objective

- Students' third racing bot should be faster than their first.

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit(s)

Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

- A long, straight, flat surface for racing.
- [Optional] Tape to mark a start and finish line.

Preparation

These tasks should be completed prior to running the activity:

- Drivetrains should be built that provide easily changeable axles for adding/removing gears. They only need the two powered wheels and no others. Make sure the brain is securely attached.

Notes for Leader

- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.
  - Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.
- Below is a suggested drivetrain. It is a mod of the basebot to allow extra axles for additional gears.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- How to program the NXT-G brain to drive forward always using the buttons, rather than the PC software.
- How to instruct the kids how to put the drivetrains back together in case the drivetrains break.

IMPORTANT! Mentors should keep their hands OFF the robots.

IMPORTANT! Mentors should **NEVER** tell students that they're wrong. If the students cannot logic out the right answers to the mentors questions, let them try their ideas for one race, make sure they watch the result, and then let them work through what they observed to find new design ideas to try.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- There will be 3 races. One after 15 minutes, another 10 minutes later, and another 10 minutes later. The goal is to win the third race. The drivetrains should allow you to easily add and remove gears. You want to gear the robot so it drives as fast as possible without spinning out.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- How can we make the wheels spin faster than the motor?
- What happens if we put two gears of the same size next to each other?
- What happens if we put two gears on the same axle?
- What happens if we put a small gear on the motor and put a big gear next to it?
- What happens if we put a big gear on the motor and put a small gear next to it?
- What happens if our gears aren't identical on both sides of the robot?

Mechanical III 20

This chapter covers a long term mechanical project. Students design and build robots for a competition where robots try to push each other out of a ring. The mechanical portion takes 2 weeks, assuming mentors program the robots. Students can program their own bots with an additional week of time.

This chapter includes:

How To Use This Lesson Plan

This explains the information contained in this lesson plan, how it is organized, and how to use it. For more details please see the complete chapter How To Use Lesson Plans.

Background

Lesson plans are based on once weekly, two hour meetings, with children ages 7-12. These lesson plans can be modified for use by any other workshop, program, club, or classroom for their own use.

How To Read the Lesson Plans

Each lesson plan is organized into multiple sections.

The Length, Prerequisites, Compatible Common Core Standards, Motivation, and Instructional Objective sections are all designed to give context and information about the purpose and intent of the activity and some context as to where it fits in with the other lesson plans.

Materials Needed, Preparation, Notes for Leader, and What Mentors Need to Know contain information necessary prior to running the activity. It helps mentors prepare so the activity will run smoothly.

Explanation of Activity for Students, and Questions for Mentors to Ask Students should be read by the mentors BEFORE the activity as preparation but are meant as instruction for what to do during the activity itself.

How to Run a Lesson

About a week before the activity is scheduled, all teachers/mentors/leaders should read through the lesson plan. As necessary, acquire needed materials and complete preparation tasks.

Use the explanation as a guideline of how to instruct the students. You may wish to display any specific rules.

We recommend splitting students into groups of 2-3 students with 1 mentor per group for most effective participation.

In general, we do not have a post-activity discussion; we rely on the mentors to discuss DURING the activity. You may wish to have a get together at the end and have the students compare what they learned during the activity.

Instructions for Mentors

We ask our mentors to follow these guidelines to facilitate student learning by experience rather than learning by lecturing:

- Do not tell students they are wrong - let them try it and see for themselves if it works or not.
- Do not put your hands on the robot, structure, worksheet, etc.
- Do not ask long, rambling questions that are actually disguised explanations/lectures.
- If students are unequal in skill level, ask the stronger one to explain or teach the other student how to do a task.
- Facilitate the students taking turns - build one step then switch, program 1 block then switch, do 1 calculation then switch.
- For math calculations:
  - Have both students do the calculation and compare answers.
  - Tailor to skill level. Multiplying by a decimal can be the same as dividing.Have students solve the same calculation by different methods.
  - If the answer is wrong, ask them if the answer makes sense, try to explain what the result is saying, ask them if that is correct, rather than just telling them it's wrong.

Further Descriptions of Some Sections

- Prerequisites
  - Knowledge that we assume the students already possess. In general, the prerequisite knowledge can be found in one of our other lesson plans.
- Compatible Common Core Standards
  - We understand that these lesson plans may be of interest to K-12 outreach programs and classroom teachers. We have tried to identify which Common Core standards the activity overlaps with or is compatible with.
  - For more information on the Common Core and its standards, visit http://www.corestandards.org/
- Motivation
  - The motivation for the students, why they want to bother with this activity.
- Instructional Objective
  - Skills/knowledge the students should be able to demonstrate by the end of the lesson. Mentor questions and discussions with students should be aimed towards reaching these goals, in addition to simply completing the activity.
- Notes for Leader

  - These are just general notes, things to keep in mind, explanations, warnings, possible variations or expansions on the activity, and more.
- Explanation of Activity for Students
  - How to explain the activity to the students, what the objective is, what tasks need to be completed, any rules, etc. In general we recommend that these are posted somewhere visible for the students to easily refer to during the course of the activity.
- Questions for Mentors to Ask Students
  - Mentors do not need to ask all of the questions.
  - Mentors do not need to ask the questions in the order they are listed.
  - The questions are simply examples and suggestions to help train new mentors to think of how to lead and guide students by questions rather than explaining or lecturing.

Sumo Bots

Length

Without Programming:

Activity time: 3 hours

Total time: 4 hours (Includes explanation and clean-up across two sessions and competition)

With Programming:

Activity time: 4.5 hours

Total time: 6 hours (Includes explanation and clean-up across three sessions and competition)

Prerequisites

It is recommended but NOT required that students have some prior experience building with the LEGO kits.

Compatible Common Core Standards

We have identified that this activity has several components that relate to Common Core standards. You may adapt the activity as you see fit to either increase or decrease the focus on these standards.

Most activities are also compatible with Comprehension and Collaboration for grades 2-5 and Literacy for grades 2-5.

To see a complete list, please see the Common Core chapter.

Common Core Area	Common Core Standard	Robokids Related Task
General Math	Make sense of problems in solving them	Determining what makes a successful sumo bot.
General Math	Reason abstractly and quantitatively	What do they want the robot to do. How do they build that?

Motivation

There are multiple ways to accomplish the same task, but some can be more effective than others. We're going to have a competition to see which groups manipulator is the most effective.

Instructional Objective

- Students should be able to articulate a specific plan for what they want to build.
- Students should be able to articulate the reasons why they chose their design, especially in terms of cause/effect.

- Students should be able to identify specific mechanical reasons why the winner bot was the most successful instead of the other bots.

Materials Needed

You will need these materials to run the activity:

- LEGO Mindstorms robot kit(s)

Note: We recommend 1 kit per 2-3 students. See Chapter 1, How to Use Lesson Plans for more information.

- Laptops/computers with NXT-G software installed
- A method of displaying videos
- Videos of "LEGO sumo bots" and/or "battlebots"
  - http://www.youtube.com/watch?v=qSI_Ldy1l2A
  - http://www.youtube.com/watch?v=vtB8xqXY_gk
  - http://www.youtube.com/watch?v=aRY6Y8OrZFk
- A circular platform approximately 3ft in diameter and between 0.5 and 6 inches in height. Circle should be black with a 1" thick white border around the perimeter.

Preparation

These tasks should be completed prior to running the activity:

- To save time, build the basebots ahead of time. If the students wish, they can modify the bases, but this gives less experienced students a simple platform to begin with.
- Build the competition arena. See the description of the circular platform in Materials Needed.

Notes for Leader

- This is a longer activity. We recommend a snack break or other pause about halfway through.
- Depending on the experience level of the students, this activity can easily be made harder or easier. To make it easier, build the basebots and program the robots for the children, allowing them to focus on building manipulators. More experienced students can complete those tasks on their own.
- Be aware of your student groupings.
  - You may wish to keep the experienced students separate from rookie students - this will keep students within a group on an equal level so that one does not dominate and the other is pushed to the side.

- Alternatively, you could purposefully mix experienced students with rookies. In this instance, we strongly recommend you prepare your mentors to facilitate the more experienced student to teach and explain to the rookie student, rather than just doing.

IMPORTANT! If the activity is split over multiple sessions, label each kit and robot with the group names so that they can be easily returned to their students.

- It is specially crucial for this activity that the mentors do not tell the students what to do, or strongly suggest what will be "best". They should focus on encouraging the students to develop their own ideas, designs, and hypotheses.

What Mentors Need to Know

Mentors should be familiar with the following to best assist the students during the activity:

- How to connect LEGO pieces to avoid rotation and flimsiness.
- How to ask the students their ideas, and how to encourage the students to develop and implement their own ideas.

IMPORTANT! Mentors should **NEVER** touch the robots.

IMPORTANT! Mentors should **NEVER** tell the students that they are wrong.

Explanation of Activity for Students

It is best if you post the instructions in a place the students can easily see. This will help keep them on task and help minimize confusion.

- Show videos of other sumo bots. Discuss what the kids notice in the videos (sensors, types of manipulators, strategies: flipping, pushing, etc.)
  - http://www.youtube.com/watch?v=qSI_Ldy1l2A
  - http://www.youtube.com/watch?v=vtB8xqXY_gk
  - http://www.youtube.com/watch?v=aRY6Y8OrZFk
- Explain rules:
  - Must fit on a sheet of 8.5"x11" paper
  - Must have a light sensor pointed towards the ground
  - Will cover two sessions. All building this session, half of next session will be building and the second half will be competition.
  - Mentors will program robots

– Bracket style tournament

  Whichever robot first has a wheel pushed off the edge of the competition platform loses the match.

Questions for Mentors to Ask Students

These are questions and explanations we have found to be helpful for mentors to use while working with the students.

- What do you want your robot to do?
- What are ALL the possible attachments you could add to your robot?
- What LEGO pieces will you need to build that?
- How can we keep two straight pieces from twisting/spinning?

  Attach them using 2 pins side-by-side instead of 1 pin.