RoboKids IQP

An Interactive Qualifying Project Report

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ABSTRACT

This project is to create a robotics curriculum for middle school students that can be presented by teachers or volunteers that have no knowledge of robotics. The curriculum is broken into a sequential set of units which build off of each other. Each unit concentrates on a specific subject and includes a video presentation and related activities. The first unit introduces the concept of a robot and the students build a simple robot base and learn how to make it move.

ACKNOWLEDGEMENTS

The authors would like to acknowledge a number of people for their contributions to this project. We would like to thank Martha Cyr for her contributions to our knowledge base. We would also like to thank Andrew Oprea for recording the voices for the videos for each of the lessons. Finally we would like to thank our project advisors Brad Miller and Colleen Shaver as well as all the respondents to our survey.

AUTHORSHIP PAGE

Both members of the project team contributed equally to the creation of the curriculum. Additionally, both contributed equally to the creation of the paper. In addition to recording the voices for the videos, Andrew Oprea was also a contributing member of the original project group and aided in some of the initial curriculum design as well as the beginnings of the paper.

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EXECUTIVE SUMMARY

OBJECTIVE OF THE PROJECT

The RoboKids IQP was undertaken to create a robotics curriculum for the RoboKids program of the Friendly House Community Center in Worcester, MA. However, the current methodology used to teach the children was found to be lacking and the need was identified for a curriculum to guide volunteer mentors in this instruction. Ideally, the curriculum defined by this project could be expanded to address the needs of not only after-school programs, but regular classroom instruction as well. The overall objective for this curriculum was to be comprehensive of material appropriate for middle school-aged children while maintaining a significant level of interactivity to keep them engaged.

BACKGROUND

In order to gain a better understanding of the current state of both the RoboKids program and robotics education as a whole, background research and observations were conducted. The programs addressed for comparison to this curriculum included LEGO® Education, LEGO Engineering®, the NASA Curriculum Clearinghouse, the CEEO at Tufts University, A World in Motion, FIRST LEGO® League, and the current RoboKids program. In addition to the currently established programs, research was done into educational standards as well as previously conducted educational studies on the effectiveness of using LEGO® bricks in a curricular environment.

The RoboKids curriculum, proposed in this document, is designed to fulfill most of the engineering and technology requirements for sixth through eighth grades as well as to be used by existing teachers with minimal retraining. Without such a program, most schools will find it necessary to recruit and pay a new set of teachers with specialization in technology and engineering or to retrain existing teachers.

WHAT WAS DEVELOPED

At the highest level we split the curriculum up into three main units.

The first of these units was meant as an introduction to the field of robotics and is intended to get the children's feet wet before they delve into more advanced topics. The aim of the first lesson is to teach the children about what makes a device a robot and allow them to brainstorm about robots that they might have encountered in their daily lives. This flows into the children beginning the construction of their own robots. The first design is taken from the BaseBot instructions for the LEGO® MINDSTORMS® NXT kit as that has been developed by LEGO® for use in an educational environment and includes detailed instructions for the children to follow, consistent with standard LEGO® instructions that they might have previously encountered. The construction of this BaseBot includes a bumper with integrated touch sensor so that upon completion the children can manipulate and interact with the device. Once the children have familiarized themselves with their BaseBot, the initial unit concludes with an introductory lesson on programming their robot. This initial foray into robot programming includes simple tasks like driving forward, waiting on sensor input until the robot hits a wall, and then backing up and turning to proceed in a new direction.

The second unit consists of the bulk of the material with further programming exercises, an introduction to sensors, and material on actuators and effectors. The first lesson continues upon the sensor material that the students were introduced to in the first unit. The touch sensor was introduced with the BaseBot so that the children would have instant gratification after they had completed the construction of their first robot. This introductory material was expanded upon to include further information on the touch sensor as well as information on the infrared, ultrasonic, and integrated rotation sensors on the motors. Students were asked to perform a series of tasks to strengthen their understanding of the advantages and disadvantages of these various sensors. The next lesson developed material on the use of actuators to drive robotic mechanisms. These mechanisms were introduced as mostly consisting of effectors. The children were asked to expand upon their initial BaseBot in this lesson by adding arms that could be programmed to grab and otherwise manipulate a ball. This was the first lesson to truly integrate the use of programming as well as sensors and effectors to convey robotic concepts to the students. Programming examples and further information on conditionals, looping constructs, and generally accepted effective programming practices were included in the third lesson of this unit. The final lesson was included to provide an introduction to the concept of gears. This included examples of gear ratios and the concept of torque.

The final unit consists of an integrated design project to test what the children learned throughout the curriculum and to provide a means for the instructors to evaluate the children. This project is presented as a design challenge similar to the FIRST LEGO® League Competition.

The development of lessons mainly focused on five areas: instructions to students, instructor preparation material, definitions, videos, and worksheets. Each of these areas was used as a place to focus our design and to provide material to both the teachers and students as support for our curriculum.

RESULTS

It is clear from the research and responses that we have received, that we are developing a viable curriculum that would successfully introduce middle school-aged students to the concepts outlined in the RoboKids curriculum. The majority of the responses were favorable to both content of the program and the methodology of introducing the information. The authors have received requests from the reviewers for our materials with the expectation that they could pilot it for their school. This would be important and needed to direct further refinements. The authors recognize that this project is only the beginning and that further work will be required by future WPI students. Nevertheless, we are optimistic that our approach will give both teachers and volunteers the confidence they will need to implement such a program in their school.

INTRODUCTION

Despite the importance of engineering to our society, instruction in this topic is often absent in public schools. Fortunately, programs to introduce students to engineering are becoming more common and are providing anecdotal evidence of their effectiveness. One example is in Warren, Ohio, where only 50% of high school freshman graduate in four years with their class. In this challenging environment 100% of the participants in the school's robotics team not only complete their high school education on time, but go on to higher education or military service.[1] This example is just one of many that demonstrates the value of introducing engineering to school-aged children.

Answering this charge, RoboKids is an established out-of-school program of the Friendly House Community Center in Worcester, MA where youth are mentored by Worcester Polytechnic Institute (WPI) students as they design and build robots while also gaining an inherent knowledge about engineering and robotics. However, the current methodology used to teach the children was found to be lacking and thus WPI student project coordinator Sabrina Varanelli identified the need for a curriculum to guide volunteer mentors in this instruction. Developing a curriculum and instructional materials was undertaken as an Interdisciplinary Qualifying Project (IQP) by the authors. In consultation with advisors, the decision was made to expand the project scope to developing a three-week, or 15 class curriculum that can be taught as either a curricular or extracurricular activity. The target audience for the program is middle school students, but the possibility should still remain for expansion to other target age groups.

Given this motivation, the objective of the RoboKids IQP is to design a comprehensive, interactive engineering curriculum for middle school students that can be delivered without much cost or added pressure of finding technically trained instructors. This course engages students in hands-on projects in order to illustrate key engineering concepts. The first unit introduces students to the field of robotics, including building and manipulating a basic robot. The second unit includes material on engineering subjects spanning the core robotics fields of mechanical engineering and computer science, with lessons including sensor selection and usage, effector design, and programming methods. The third and final section is a design competition for students to test not only their creativity and problem-solving skills, but also their new knowledge about robotics.

In addition to the academic content, there are a number of other instructional factors that are addressed by the curriculum presented in this document. One such factor is that student distraction is minimized by introducing only the components of the LEGO® MINDSTORMS® NXT kit that will be used in the current lesson. Another factor considered is the possibility that the teacher will have little or no experience with robotics or engineering. For this reason, the curriculum is designed so that it can be taught strictly from the provided materials. The final consideration is ensuring the availability of all materials used in the curriculum. To this end, all the components of the curriculum were chosen to be easily available in any area of the U.S. as well as the rest of the developed world.

BACKGROUND

OUR INVESTIGATION

Investigation for the RoboKids curriculum began with a review of existing instructional resources and a review of the relevant literature. The *FIRST* LEGO® League, the NASA Robotics Curriculum Clearinghouse, and the Center for Engineering Education and Outreach (CEEO) at Tufts University were identified as best practices and thus design concepts from these resources are included in the proposed RoboKids curriculum. A summary and analysis of project research follows.

LEGO® EDUCATION

LEGO® supports an entire educational division. This part of the corporation collects, creates, and disseminates activities and lesson plans that meet a variety of educational standards. LEGO® Education also employs a liaison for each major region of the United States who helps educators find programs and supporting materials that allow the educators to teach engineering concepts. Some popular activities showcased by LEGO® Education North America are: "Beat Box" (create a LEGO® synthesizer), "Applause, Applause" (build an applause-meter), and "Light Control" (use a light sensor to control a motor). [2]

LEGO ENGINEERING®

LEGO® Engineering is a resource that brings together material for teaching engineering through the use of LEGO® bricks and LEGO® MINDSTORMS®, including the NXT system that is used for the RoboKids curriculum proposed in this document. Throughout the year, LEGO® Engineering holds conferences and conducts research into the use of the LEGO® system in the classroom. [6] This resource is a collaborative effort of both the Tufts University Center for Engineering Educational Outreach and LEGO® Education.

NASA CURRICULUM CLEARINGHOUSE

NASA maintains a collection of resources for educators on the subjects of engineering and technology. In their Robotics Curriculum Clearinghouse (RCC) they provide access to educational material as well as links to robotics competitions and other similar educational opportunities. In addition to the RCC, NASA provides material for educators to teach their students about NASA spacecraft, rovers, and missions. [3]

CEEO AT TUFTS UNIVERSITY

The Center for Engineering Education and Outreach (CEEO), affiliated with Tufts University in Medford, MA directly teaches students about engineering as well as teaching teachers methods of instruction appropriate for an engineering curriculum. To this end, the CEEO administers the Student Teacher Outreach Mentorship Program (STOMP) [3] network as well as LEGO® Engineering. [5] The STOMP network places Tufts students in classrooms to help teachers learn to teach engineering topics to elementary and secondary students.

A WORLD IN MOTION

A World in Motion is sponsored by the Society of Automotive Engineers International and funded by numerous corporate sponsors to provide curricular tools for teaching science, technology, and mathematics at the primary, elementary, middle, and high school level. A project kit includes a highly developed teachers manual, lesson plans, instructional videos for students and teachers, parts kits, and competition guidelines. The cost of kits vary from $120 for a glider project for 15 students, to $295 for the car project kit, to $380 for a fuel cell classroom kit that serves 9 students, while some complementary project kits are also available to teachers. The materials are of very high pedagogical quality, but the program is designed to include a classroom teacher and a volunteer scientist or engineer. Extensive materials are also provided to assist in recruiting, training, and retaining volunteers. These project kits could prove beneficial to a program like RoboKids and the use of their models should be considered for future development of instructor training materials. [7]

FIRST LEGO® LEAGUE

The FIRST LEGO® League (FLL®) program, run by the not-for-profit *FIRST* (For Inspiration and Recognition of Science and Technology) organization, was started in 1988. It is primarily a competition designed to get students excited about science, technology, and engineering as well as to provide instruction to these students. The program has spread to reach 135,000 students in 45 countries and those are just the students that are officially registered for the competition. [8] Since the FLL® program relies on skilled instructors, detailed instructional materials are not provided to participants. Each year's competition includes a thematic subject such as nanotechnology or renewable energy. Teams investigate these topics and compete with their research as well as in the game designed as a robotic competition. This structure provides multiple ways for students to engage in activities relevant to the topic, but it also dilutes the students' concentration on building robotic and engineering skills. There are a number of groups, including RoboKids who use all or part of the FLL® games informally. The integrated design project in the RoboKids curriculum borrows the concepts of a design of a problem undertaken by a single robot on a field of play and a home court where the robot can be modified by the team from the FLL® competition, while simplifying the problem presented, the length of the instructions, the equipment options, and the length of play.

ROBOKIDS

RoboKids is an established out-of-school program of the Friendly House Community Center in Worcester, MA. Offered once a week during the WPI school year, the RoboKids program allows college students to teach middle school students about engineering and robotics. The current program covers a range of subjects that vary from simple programming and drive trains to the use of sensors and advanced manipulators. The culmination of the students' experience is an informal competition using a recent *FIRST* LEGO® League challenge.

OUR THOUGHTS ON EXISTING PROGRAMS

The most limiting aspect of the existing programs and curricular tools are that they require a teacher with knowledge in the field of robotics. This additional requirement prevents many schools and out-of-school programs from offering courses in robotics. To become involved in one of the previously listed programs, a school would have to either hire a new teacher or invest in additional training for one of their current teachers. Many schools and community programs, especially those in low-income districts, are unable to undertake this expense.

The students at these under-resourced schools, however, deserve access to the same kind of introductory robotics course that is available to the schools participating in the existing programs. To fulfill this requirement, we are developing a robotics curriculum that does not require the teacher to have any prior knowledge of the subject. The curriculum uses a series of videos and activities to teach engineering and problem solving concepts.

RESOURCES AND REGULATIONS

In addition to looking at other curricula, we also looked at educational standards as well as educational resources. These sources enumerate the learning objectives that teachers have to cover in their classes and suggest the best ways to present this information.

AN EFFECTIVE STANDARDS-BASED K-12 SCIENCE AND TECHNOLOGY/ENGINEERING CLASSROOM

An Effective Standards-based K-12 Science and Technology/Engineering Classroom states that "Students learn when they are personally invested and engaged, and there is arguably no more engaging subject areas than science, technology, and engineering! Students actively participate in learning when they understand the relevance of a lesson, regularly communicate their thinking, reflect on their experience, and apply content knowledge, inquiry skills, and engineering design to the world around them." (MADOE, 9/07, 1) This paper explains methods of teaching science, technology, and engineering with educational standards in mind. It goes so far as to say that it is essential for people to know those subject matters in order to live in modern society. [10]

According to this article, the most important factor in effective science, technology, and engineering education is that the students are active participants in their own education. This precept is the basis of our new RoboKids curriculum. Other factors that the paper introduces include providing more than one possible explanation for the same observation and creating different levels in the same lesson so that students with different degrees of mastery can still be involved. [11]

MASSACHUSETTS STATE EDUCATIONAL REQUIREMENTS

The Commonwealth of Massachusetts has one of the nation's most stringent set of requirements for science, technology, and engineering education. In 2001, The Commonwealth of Massachusetts Department of Education released their Science and Technology/Engineering Curriculum Framework, which revised their 1995 Science and Technology Curriculum Framework. It is noteworthy that the area of engineering was added to this newly revised framework and grouped with technology to create the Technology/Engineering content strand. Since this new content strand was added to the state's competency determination, this means that the Department of Education believes that it is essential for students to have an understanding of technology and engineering to be productive members of society. [12]

STUDIES REGARDING THE USE OF LEGO® BRICKS IN AN EDUCATIONAL ENVIRONMENT

In our background research, we reviewed several studies that have been previously conducted regarding the use of LEGO® bricks in an educational environment. The *Study of Educational Impact of the LEGO Dacta Materials – INFOESCUELA – MED* is one such example that was conducted in Peru as a study of "the pedagogical effects caused by the application of LEGO Dacta materials in different schools of the country." [13] Another study is *Does lego training stimulate pupils' ability to solve logical problems?* which was conducted as a continuance of the INFOESCUELA study and investigated student performance as a result of one year of regular instruction using LEGO® bricks. The impetus of both of these studies seems to be centered on the pedagogical perspective of constructionist theory, the idea that knowledge is constructed in the mind of the pupil by active learning. [14]

METHODOLOGY

PROJECT SCOPE

There are a number of highly successful programs designed to introduce middle school students to science and technology. The design of these programs ranges from the traditional academic curricula designed by NASA and Tufts University to extracurricular programs such as the *FIRST* LEGO® League (FLL®). Each is successful in different ways, yet many children still do not receive a satisfactory introduction to science, technology, and engineering. After review of existing programs, the cost of participation and the need for instructors with advanced knowledge of robotics were identified as substantial impediments to expanding robotics, science, and engineering education within schools and community programs. Therefore, this project was developed to facilitate instruction by individuals with limited knowledge of robotics. Another consideration was that instructors and students in volunteer programs such as RoboKids often attend sporadically during the course of an instructional sequence. Therefore, the proposed curriculum relies heavily on video instruction and a prepackaged project with detailed instructions.

PROJECT GOALS

The overall objective for this curriculum is to be comprehensive of material appropriate for middle school-aged children while maintaining a significant level of interactivity to keep them engaged.

Pedagogical goals include:

- Instruction through active participation in hands-on projects
- Building problem solving techniques
- Developing student interest in science and engineering
- Eliminating elements that distract students
- Provide a standards based curriculum

In order to facilitate widespread use of the curriculum, it was designed to:

- Be used by teachers without previous experience in robotics or engineering
- Primarily incorporate reusable materials
- Employ standard, widely available LEGO® MINDSTORMS® NXT kits

OBSERVATIONS

In order to accomplish our goals, some observations were made so as to better direct our design. The most immediate source for us to use was the currently established RoboKids program itself. The conclusions derived from observation of that group were instrumental in shaping our initial design since those were considered the most immediate concerns if our curriculum was to be adopted by the RoboKids program. Additionally, we consulted published studies on the results of using LEGO® bricks in a classroom environment in order to better understand the current knowledge on the subject. Many of the conclusions that came from these studies supported our observations of the RoboKids program as well as providing additional details to aid in our design.

ROBOKIDS

Throughout the course of this project, the members of the IQP project group attended the RoboKids program to observe and to assist with the various activities. These observations assisted the authors to better understand the manner in which the program operates and to determine which elements of the existing practices should be incorporated in the new RoboKids curriculum. We also observed the children's learning styles in order to gain insight into the way in which we should structure the lessons and the activities encompassed by the RoboKids curriculum.

The overarching observation of the IQP group was that since RoboKids is an after-school activity, the group of children was not necessarily the same each week and the children did not necessarily know each other very well or have experience working together in groups. The attention span of the children also seemed to support an activity lasting up to about half an hour to 45 minutes and was something that was taken into consideration while timing our lessons.

As the college student mentors were going through the activities with the children, we observed that some concepts were difficult to convey. In particular, the children appeared to have difficulty understanding the limitations of the robot they constructed. Specifically, participants seemed to believe that they would be able to program the robot to undertake any activity they themselves could accomplish by physical manipulation of the systems. For example, they could attach an axle piece to their robot and proceed to poke a mechanism with it, though not without difficulty. They failed to realize that actually programming the robot to perform this task would be nearly impossible, especially since the action was not even always repeatable when performed manually. As a result, it was noted that the constraints and capacities of the robot to be used for the final project need to be addressed early on in the curriculum. Also, many students, some of whom were younger than the target age group, were unfamiliar with the concept of angular measurement, as in a 90 degree turn to the left or right or a 180 degree turn.

In addition to conceptual issues, the LEGO® bricks themselves seemed to be contributing to problems with classroom management. Children were distracted by and playing with parts not required for their current project. In addition to the distraction, this also led to bricks being misplaced. To combat these issues, the number of LEGO® bricks available to the students at any one point in time should be as minimal as possible.

We also found from our observations that the youth appeared to have difficulty distinguishing the function and operation of different types of sensors. Students engaged in the current final project also appeared unprepared to think about accomplishing a task that required several steps in terms of programming the robot to, for example, drive straight ahead, wait for a touch sensor to be hit, back up, turn, and then proceed in a new direction.

STUDY ANALYSIS

Our analysis mainly focused on the *Does lego training stimulate pupils' ability to solve logical problems?* study mentioned in our background research for its observations of students within the appropriate age group.

DOES LEGO TRAINING STIMULATE PUPILS' ABILITY TO SOLVE LOGICAL PROBLEMS?

Nearly 10 years after the Peruvian study, [13] LEGO® Dacta approached a group of researchers to perform a one-year evaluation of the use of LEGO® bricks in Swedish schools. They were interested in the locale change to Sweden because of its complex student evaluation process as well as an increased likelihood of the students' exposure to various forms of technology prior to the study being conducted. This seems applicable to what we are trying to accomplish in our program since it is now rare for students in the United States to not have been exposed to technology from a young age. The Swedish study outlines a number of quantitative and qualitative results, though the latter seemed more relevant to us during the design process. The qualitative results can essentially be broken down into four areas: learning strategies, what the students learned, their learning context, and the role of the instructor. [14]

LEARNING STRATEGIES

In the area of learning strategies, this study found that most students tended toward learning by trial and error, though some students were observed to try to reach a cooperative solution by working with some of their classmates on a problem. For the most part, this involved singling out their peers that seemed to know what they were doing. Written instructions to the students seemed to be used minimally, though there was a positive response to instructive pictures, as students would at times look to them for assistance. It was observed that boys were less willing to follow directions whereas girl typically concentrated intently on following written tasks.

WHAT THE STUDENTS LEARNED

Through voluntary cooperation amongst students, as well as purposeful division into groups, the students seemed to learn how to interact well with teammates. Ultimately, student interviews suggested that there was a positive reaction to working in teams as the students felt that they had gained a feeling of community from the experience. In addition to learning about group dynamics, the students involved in the study seemed to grow in their understanding of computer programming. In the beginning only simple programs were being used, but by the end students were able to design complex programs to solve the given problems. Overall, there did not seem to be a significant difference in the amount learned based on either age or gender.

LEARNING CONTEXT

In order to encourage the growth of student knowledge, there were some observations made during the course of this study that would prove both relevant and beneficial to the construction of our curriculum. While interacting with the LEGO® bricks, it was helpful for the students to have a large workspace not only so that they could see all the pieces and be able to effectively manipulate them, but a large workspace also helped to cut down on the number of lost pieces since they were easier to keep track of. An additional observation regarding classroom management was that groups should consist of a maximum of two to three students per kit of parts. In order to keep the students engaged, concrete, relevant, and realistic tasks needed to be chosen for the students to work with.

ROLE OF THE INSTRUCTOR

The role of the instructor was primarily observed to be as a "mediator of knowledge and skills." This was important to helping students' understanding of the material, not just at a cursory level, but to instead be sufficiently immersed. As this was conducted in a scholastic environment, the instructors involved were classically trained teachers. Taking that into consideration, additional efforts might need to be taken in order to prepare some after-school instructors to effectively teach the material. Even among technically trained teachers, the presence of sufficient teacher preparation material was found to be beneficial. Possibly one of the most substantive observations was that it was usually valuable to have multiple teachers in classroom as this allowed for one or more to stop and discuss individual concerns with students.

The RoboKids curriculum, proposed in this document, is designed to fulfill most of the engineering and technology requirements for sixth through eighth grades as well as to be used by existing teachers with minimal retraining. Without such a program, most schools will find it necessary to recruit and pay a new set of teachers with specialization in technology and engineering or to retrain existing teachers. We also found that concentrating the curriculum on fulfilling requirements gives the lessons a more defined structure. Since educational standards are released as a curricular evaluation for students of a requisite age group, it also follows that they would be appropriate for use in an extracurricular environment.

In order to be used in an after-school environment, we saw from our observations that something needed to be done with respect to teaching the students about working in groups as well as combating disparities among those groups from session to session. This supports not only the structure of the final solution, but also its distribution method. Since our proposed curriculum is intended to be used by after-school programs, these factors were considered in its development. From our personal observations as well as those from the Swedish study, we can glean some insight into group dynamics that would be beneficial in both structuring our material as well providing supplemental materials to the instructors. The first is that the size of groups needs to remain small, preferably two to three students per kit. [14] This would encourage all the children to stay engaged with the material as well as allow all the children to participate equally in group projects. These groups should consist of not only girls and boys, but also a variety of skill levels. It was shown that boys tended not to follow provided instructions while girls did, [14] indicating that a mix of genders would be beneficial to group dynamics. Observations also showed that children tended to look to more experienced peers for guidance, [14] so in addition to mixing genders, mixing skill levels should help to encourage more deficient members to learn the material by giving them support within their group. Overall, the observations showed that by being put into groups children learned how to interact well with their fellow teammates and generally felt positively about group work while experiencing an added feeling of community. [14] Engineering and technical professions frequently make use of teams and the ability to work effectively with teammates is also a good life skill to have. In accordance with our set of goals, the ability to split children into groups also allows fewer kits to be used in implementing the curriculum and should reduce the cost to both curricular and extracurricular programs.

The ability to use fewer kits also provides a benefit to classroom management in that there are fewer parts to deal with in addition to the groups being able to spread out amongst the available space. This was supported by the Swedish study since they found that a large workspace was helpful while interacting with the LEGO® bricks. Fewer bricks in circulation as well as having a larger workspace should allow for fewer pieces to be lost and make it easier to work with all the parts. We have also encouraged the instructors of our curriculum to split the parts into bins prior to each lesson so as to only distribute the appropriate parts for that particular lesson. That should allow for the children not only to be able to find the parts that they need for each lesson, but also minimize distraction from having excess parts around with which to play. Parts lists are included for each lesson with images and descriptive names for each of the parts. This is meant to encourage the children to learn the correct names of the parts and thus be able to appropriately communicate with their fellow classmates in accordance with Massachusetts educational standards. [12]

Everyone has their own particular learning style, especially children. The Swedish study noted that most of the children learned by trial and error, which indicates a number of things to look at while designing our lessons. Instead of fighting the children's tendencies in that area, the course of our lessons needed to encourage multiple design iterations, which is also an important principle in engineering. This would allow children to continually refine their designs as they learned more about the field of robotics and to be better prepared for their final design challenge.

The Swedish study also noted that there was a minimal use of written instruction by the children, but instead a preference for the use of visual means in order to get the material across. This suggested that we should use pictures and illustrations to convey information in our curriculum. We also decided that videos would be an effective mechanism to teach the children as well as an advantage to the instructors, especially less technically proficient ones. By using videos to get technical information across, instruction should be consistent between various implementations of our curriculum and prove advantageous in both curricular and extracurricular environments.

The phraseology used by the Swedish study to describe the instructors was as a "mediator of knowledge and skills," which might be difficult for those of a non-technical inclination and the lessons need to be structured to provide the requisite information to both children and instructors. No matter what their background, our curriculum intends to provide adequate material to prepare instructors for teaching our lessons as well as supplemental materials in case they are not able to or otherwise prefer not to develop their own. When teaching this kind of material, it can sometimes be difficult to address individual students as they are trying to grasp the desired concepts. In order to facilitate this process without affecting the class as a whole, it is probably best to have multiple instructors in the classroom, as supported by the Swedish study. This way at least one of the instructors can stop and help one of the groups of children while there is still another instructor around to help other groups or to address the class as a whole.

More directly related to the actual material learned by the students, a substantive claim was made that was pertinent to our curriculum. As the Swedish study showed, the use of LEGO® bricks perpetuated the student's understanding of computer programming as well as allowing them to progress from simple programs to much more complex ones by the end of the study. The use of the LEGO® MINDSTORMS® platform in our curriculum allows for students to program their robots to perform a variety of actions. At the beginning of the curriculum we start with an introduction to programming the robot including actuating the motors and waiting for sensor input, then proceed to more advanced topics like conditionals and looping constructs as well as appropriate program structure. The current instruction focuses on the use of the NXT-G software that comes bundled with the NXT kits, though this could be altered for different environments with expansion upon this noted in the recommendations section. The overarching goal is that once the children are able to conceptualize the design of a program, then they will gain a better understanding of the blocks that would be required for its implementation. The NXT-G software includes a few different modes of operation, with the highest level being used in the current iteration of this curriculum to get across the requisite concepts. This is done since blocks are already included for all of the structural elements that we are trying to teach to the children.

It was also shown in the Swedish study that in order to keep the students engaged, concrete, relevant, and realistic tasks needed to be chosen for the students to work with. This observation was taken as especially important to the curriculum we were trying to develop. From the beginning, our design focused on presenting material to which children could relate. For example, in the first lesson the children are asked to brainstorm about robots that they might have encountered in their daily lives and then, attempting to account for expected responses, the children are shown examples of which are and are not robots. Our curriculum was also designed to try to logically sequence the children through the requisite material while advancing their knowledge without immediately overloading them.

In addition to our personal observations on the RoboKids program, as well as those from the previously established studies, one of the important resources used in the development of the proposed RoboKids curriculum was the expertise of Professor Martha Cyr. Professor Cyr is the Director of K-12 Outreach at WPI and in this capacity works closely with the mechanical engineering and robotics engineering departments. She is knowledgeable about use of the old RCX control system as well as educational standards and their application. Throughout the process of developing the RoboKids curriculum, the IQP project team consulted her with respect to K-12 education. She also assisted the IQP team in reviewing the Massachusetts state education requirements as well as reviewing our interim products and work plans.

With respect to the Massachusetts educational framework, during our review with Professor Cyr we identified ways that the RoboKids curriculum could incorporate more of the state's curricular requirements. One such requirement is the Grade 6-8 skill "Communicate procedures and results using appropriate science and technology terminology." on page 11 of the Massachusetts Science and Technology/Engineering Curriculum Framework [12]. She suggested that we determine the appropriate names for the LEGO® bricks and provide that information to the instructors and the children so that the children would be able to ask for and discuss parts by the correct name.

The IQP team also consulted with Professor Cyr on the outline of the first of the three units in the curriculum. Unit1: Introduction to Robots, includes 'What is a Robot?', 'Build BaseBot', and 'Program BaseBot.' She commended us on the structure of the unit and its flow and assisted us in refactoring the unit into classroom sessions. For building the BaseBot, the suggestion was to allow for one to one and a half periods, a period being defined as a typical class length of around 45 minutes. For programming of the BaseBot, two periods was suggested and another is reserved for testing. For Unit 1, the programming is expected to take the longest period of time since the children will use the software to construct the sample programs. It might take some time for the children to learn programming techniques and there also might be a limited number of computers available for their use. The building of the BaseBot is expected to take less time since the LEGO®-provided instructions are designed for ease of use, but we cannot predict the children's abilities to stay focused nor their abilities to work effectively in a team. Children that have never used the LEGO® construction system before might experience difficulty in fitting the bricks and understanding the format of the instructions. The testing and 'What is a Robot?' lesson should take the least amount of time since each section is relatively straightforward.

Two valuable suggestions that are included in the proposed curriculum are pre-loading a test program on the NXT controller and including a bumper that includes a touch sensor on the BaseBot. The purpose of pre-loading a test program is so that the children can immediately test what they have built and thus receive instant gratification. The bumper is meant to be used with the test program as well as serving as a preliminarily introduction to the touch sensor, with the added benefit that the children get to interact with their robot in each lesson. The children should be documenting their solutions to the various problems, both for good practice as well as to provide some consistent flow, especially if some children are absent at any point in time. This includes keeping proper engineering notebooks as well as communicating appropriately about their designs and the parts themselves.

Another idea was to tether a touch sensor to the robot so that the children could control the robot's actions by remote. Unfortunately, the standard wire lengths provided in the LEGO® NXT education kit are not long enough for this use. This project could be included as an option in a future edition of the curriculum or as an extension to the program, but requires securing additional materials.

The IQP team brainstormed as a group with Professor Cyr about the idea of including a group presentation at the end of each unit. This could provide an opportunity for the children to apply the knowledge from the unit to solving a problem. It was suggested that if the children were only asked to produce one solution, the likelihood is that the children would make one design and not consider alternatives. To combat that problem, the suggestion was made that for the second presentation at least two different options should be presented, while the first presentation should be relatively simple. Hopefully the children's ability to devise a complex solution would evolve as they learn more concepts and more about the various components. These problems should allow the children more freedom to determine their own goals, select controls, and develop programming. Sample solutions could be provided to similar problems in order to facilitate the process. In addition to fulfilling at least one of the education requirements, the presentations and the child-generated goals are meant to encourage the children's involvement in the whole design process. The implementation of the group presentations was not completed within the scope of this iteration of the curriculum, but is left as a recommendation toward future works.

METHODS

The development of lessons mainly focused on five areas: instructions to students, instructor preparation material, definitions, videos, and worksheets. These areas were believed to be the most beneficial to convey information about the field of robotics as well as preparing the instructors to effectively handle getting that information across to the children. Through the analysis of our observations, and as noted in the design section, children seemed to respond well to the use of visual aid in the conveyance of information, while written instruction did not seem to be directly favored. This led to the approach of using illustrative images in addition to the written material to accommodate as many learning styles as we could, in addition to the noted gender-based disparity among the use of provided instructional material

The goal of the sequence of lessons is to teach engineering problem solving through a series of robotic projects. Each project introduces one or more core engineering concepts. Lessons include:

- Taking a problem and breaking it into its components
- Introduction to computer programming structure and logic
- Basic mechanical engineering concepts such as gear ratios, effector design, and actuation
- Determining the capabilities and possible uses of various effector as well as sensors, including ultrasonic, infrared, and touch

Typical classes include a video that introduces the lesson topic and a student team project. Student projects are supported by instruction manuals, challenges, and/or additional video clips. The children work in groups for all projects and as noted from our observations the student teams are recommended to consist of two to three children, while groups of four also appeared successful.

In groups of five or more it was difficult for all of the students to participate fully and as a result many students disengaged.

LESSONS

For reference, this is the outline that we followed in designing the lessons for our curriculum:

- **Unit 1:** Building You First Robot
  - **Lesson 1:** What is a Robot?
  - **Lesson 2:** BaseBot
  - **Lesson 3:** BaseBot Programming
- **Unit 2:** How Robots Interact with the World
  - **Lesson 1:** What are Sensors?
  - **Lesson 2:** What is an Effector?
  - **Lesson 3:** Programming Examples
  - **Lesson 4:** Gear, Gears, Gears
- **Unit 3:** Integrated Design Project

Throughout the construction of the lessons for our curriculum, we needed to make a number of decisions regarding both structure and functionality. The primary concern going in to the curriculum development was what material to cover and what extra materials to include for both the instructors and the children. In order to accomplish this, the background information, observations, and design work along with personal experience were combined to find the best solution.

To decide what material would be best to cover, we looked at what subjects were taught in other curricula and considered what would be most important to building a robot. While considering the variety of material that needed to be covered in this curriculum, a decision was made to not include any lessons on electronics. This decision was made because the NXT kit comes with all of the wiring pre-done. The curriculum would instead focus on the mechanical and programming aspects of robotics. This still left us a lot of material to be covered in order to give the children all the requisite knowledge for designing and building their own robots.

From the studies on the use of LEGO® bricks in education as well as from observation, it has been shown that they are most effective when the children get to interact with the various parts and are able to relate what they have learned to something practical. In order to get this interaction, it was decided that each lesson would include a project where the students would be able to build or program their own robots. The problem seen with this feat was that there is only a limited time in each class period, so it would be impossible to build a completely new robot for each lesson. Because of this, we chose to have the children follow the instructions included with the LEGO® MINDSTORMS® NXT kits to build a BaseBot. This was done within the first unit so that the BaseBot could then be built upon in subsequent lessons. For example, the mechanical lessons would add new arms or gear trains on to the BaseBot, while the programming lessons would involve making the robot perform new tasks.

INTRODUCTION

The decision was ultimately made to start the curriculum by introducing the concept of a robot. Since the curriculum is based around the field of robotics, it seemed important to introduce the children to the subject before proceeding to any further lessons. Additionally, by starting with an introductory lesson, the children would be able to build the BaseBot as the first project before needing to use it in the following lessons.

Once the students have been introduced to what a robot is the authors decided that they should build the BaseBot. It was decided to use the BaseBot instructions that come with the NXT kit because it is simple to build and each kit already has an instruction booklet with instructions on how to build it. Additionally using the provided BaseBot allows for many of the default settings in the programming section to work further reducing the complexity of the curriculum.

MECHANICAL

For the mechanical lessons, three important subjects were chosen for this initial inception of the curriculum. The three subjects chosen were gears, actuators, and effectors. Effectors are the devices that robots use to interact with the world around them. These devices are shown in many of the other curriculums that were looked at for the background. Similarly, observations of RoboKids showed the importance of showing students how effectors work and what they can be used for. It was decided that actuators would also be included in the effectors lesson. This decision was made because the actuators, servos and motors, are not particularly useful without some sort of effector to use the motion. Gears were chosen for similar reasons to effectors. Gears are used on all sorts of robots and other devices to adjust the speed and torque at the output of an actuator.

It was also important for the mechanical lessons that the children to be able to create working models of the material covered in the classes. This would help the children visualize the concepts that they were being taught. Another important factor is the limited time for each lesson. To accommodate these two requirements the effectors lesson uses a simple arm which has directions that are included in the kit. This allows a child to see how an effector works and learn how to use it without having to spend the time for each group to design their own arm. Similarly, for the gears lesson, the authors created a set of gear trains that could be mounted on the BaseBot. The gear trains are designed to be easy to build and demonstrate the different concepts shown in the lesson.

PROGRAMMING

The programming side of the curriculum is more complex due to the fact that many of the aspects of the programming design rely on other sections of the curriculum. In order to decide what programming subjects should be included in the curriculum, the authors first looked at others of the background curricula. In addition, the authors used their observations of RoboKids and personal experience to determine the subjects that should be included.

A strictly programming class would have a different set of requirements for what information to get across then this class. In a traditional programming class the programming starts with basic logic concepts and slowly moves to more advanced ones. However many of the more advanced programming concepts are the ones that are required to program robots. Because of these considerations it was decided that the programming lessons would use a just-in-time teaching method where the concepts to make a program are introduced as they are needed rather than just teaching about the concepts. Part of the WPI definition of a robot is that it takes in information. In order for students to make devices that qualify as robots they need to know how to use sensors. With this in mind the programming was broken into two sections. The first would introduce the basic concepts of programming as well as how to use sensors. The second would cover general programming practices and example applications.

SENSORS

In the RoboKids curriculum, the NXT sensors are introduced one at a time to facilitate the children gaining an understanding about each sensor. By the end of the RoboKids course, this approach should help students with their ability to distinguish the pros and cons of each NXT sensor for a given task. The sensors lesson has three separate projects each of which introduces methods to use the different sensors. The first project is designed to show the capabilities of the infrared sensor as well as the logic required to follow a line. This includes conditional statements as well as loops. The second and third projects are quite similar in terms of both robot actions and programming. In the second project, the robot is programmed to use a touch sensor to bounce off walls. The third program in the sensor lesson is designed to show the advantages of the ultrasonic sensor by allowing the robot to move around and avoids walls without touching them. Each of these projects introduces the advantages and hopefully the disadvantages of the different sensors that can easily be used as part of the NXT kit.

FINAL COMPETITION

With the second unit of the lesson plan decided upon, we needed to decide how to conclude the lessons within the final unit. From the observations of the RoboKids program as well as looking at the *FIRST* LEGO® League program, the authors found that having a competition where the children design and build a robot is a very effective method for getting the children to apply what they have learned. To this end, it was decide to create a simple competition for the third unit that would allow the students to demonstrate their knowledge.

For this final unit of the curriculum, we designed a small competition that introduces the children to better understand designing and program their own robots. If the curriculum is used as an introduction to the *FIRST* LEGO® League, then the last unit is not necessary. In this lesson it was important to keep the cost of the materials down as well as making sure that they are easy to acquire anywhere that the curriculum would be used. This project includes a number of aspects that the students have not come up against before. When designing the competition, the first thing we looked at was other LEGO® competitions. These competitions were examined to consider what tasks a LEGO® robot would be able to effectively accomplish. From this information the authors created a simple competition that is based upon the things that were taught in the second unit of the curriculum.

VIDEOS

Each of the videos created for the curriculum was done separately and independently of one another. The videos were mainly used to serve two distinct purposes in our curriculum. Some of the videos were linked to a lesson and provide an introduction to the topic. We structured the lessons to begin with a video overview of the base topic to be covered in that particular lesson, then moved on to present more detailed information related to that topic. The other videos were used to refer to smaller snippets during a lesson, like stepping the children through writing a program for their BaseBot.

"What is a robot?" is a question that often gets asked and we thought it best to be answered effectively in the first lesson. In order to better answer this question, we chose to use the WPI robotics department's definition of a robot: a device that takes in information, processes it, and takes some action based on those results. Once this concept had been explained, the next stage of the video was formulated to show examples of this definition. Prior to showing the video, the instructor was encouraged to ask the children about any robots that they might have heard about or seen in their daily lives. Once the students had been introduced to the concept of what a robot was, the video tried to anticipate the majority of the robots that the students might have come up with. Though it would have been impossible to list every robot that the children may have considered, we chose a few areas where we had personally encountered robots and felt that the students would have been most likely to as well. Even with a larger list, it would have been impractical to explain why each and every one was or was not a robot without getting overly repetitive. Instead, the video chose to cover at least one robot each category so that the students could get the answer to their question even if the particular device that they thought of was not mentioned. Once the video explaining the example set of devices and the reasons that they are or are not robots has been shown to the students, they should be able to determine whether or not the items that they came up with were indeed robots.

With the overall structure of the "What is a robot?" video defined, the next step that was taken was to actually create the video itself. The first stage of this process was to decide on exactly which devices to include as examples. This process involved creating a sufficiently varied list of such devices that were both affiliated with the previously selected categories and that would be easily identifiable by the children. After choosing the devices the next step in creating the video was to show each device and why it is or is not a robot. In order to show each device, we needed to find pictures and in some cases videos of each as well as recording audio that explained whether the each particular device is a robot or not.

The gears lesson starts with a definition of a gear and then moves in to more detail. The video is designed to give an explanation of all the different types of gears available in the NXT kit. The process of making the video was integrated in the process of making the entire lesson. In the lesson the students build structures to test different gear trains and their capabilities. By recording video of the different gear trains that the students would build the explanations of how gears work can be made easier to understand. The first set of gears that the video introduces is spur gears; the most basic type of gear. Using these gears the video demonstrates the capability of gears to change the speed of a shaft as well as the torque that it produces. Once the basics of gears have been explained the video moves on to show the capabilities of the more exotic gear sets. These gear sets can produce much higher reductions as well as change the orientation of the axel rotation.

Once the raw video was recorded, found, or otherwise created it was edited together in iMovie to create each video. The audio for the gears lesson was also recorded using iMovie while the audio for the introductory and arms lesson was recorded using audacity.

SURVEYS

In order to evaluate the material that we put together, we decided to survey teachers with experience in the subject area and/or students in the target age group. Our evaluation consisted of selected representative areas for the teachers to look at, including both viewpoints on the material, the content itself, and general information related to the program as a whole. In order to evaluate the different viewpoints, teachers were asked to use their classroom experience to evaluate how they felt that their students would feel about the material in a few specific areas and to evaluate how they themselves felt about the material.

The questions related to the students' viewpoint were: "My students would find working with LEGO® bricks engaging/useful", "Directions for students are clearly written", "Programming instructions are clearly presented", "Instruction is at a level appropriate for my students", and "My students could benefit from this type of instruction." Additionally, the questions related to the teacher's viewpoint were: "Material would be easy to use", "Materials are easy to understand", "Format/design of lessons is one I would feel comfortable in using", "Extent of detail in lesson plans is sufficient for me", and "The lengths of the lessons seem appropriate." For content-related inquires we asked teachers to rate the instruction to students, definitions, videos, LEGO® bricks, and worksheets with respect to their value as an instructional tool. We also felt it important to ask whether the materials that we provided for their review need more or fewer instructions to students, instructor preparation material, definitions, videos, and worksheets. The summary of the survey results can be seen in the results section as well as the individual responses themselves in the appendix.

RESULT AND DISCUSSION/ANALYSIS

As noted, our evaluation consisted of a representative group of teachers to evaluate the effectiveness of our proposed curriculum. They were asked to look over the BaseBot Programming and Gears, Gears, Gears lessons as we felt that those were illustrative of both the different types of material that we were trying to cover, as well as the methods that we intended to use.

We obtained approval from the WPI Institutional Review Board (IRB) to perform a survey on this group of participants. The participants were informed of their rights regarding this evaluation and as per IRB guidelines were not required to complete every question and thus some inconsistencies might be observed among the quantitative results. The survey was sent out to a total of 25 recipients and received a response from 9 of them. A summary of the results gathered from this survey follows.

The majority of respondents are teachers from public schools, specializing in mathematics or an engineering discipline.

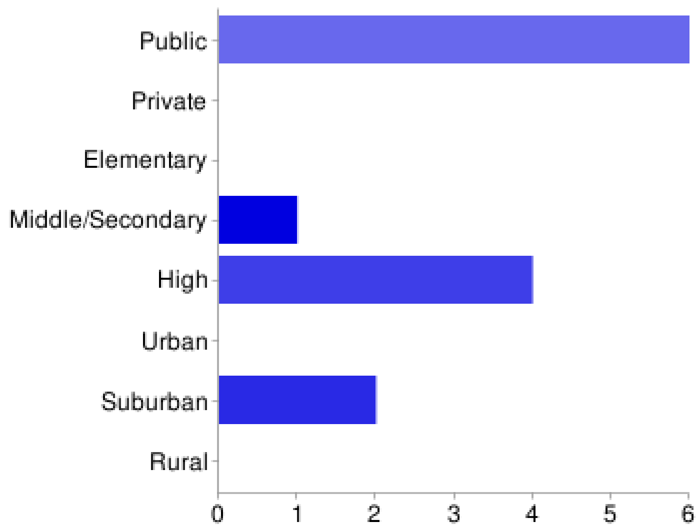

FIGURE 1: TYPE OF SCHOOL BREAKDOWN

The majority of respondents believed that their students would find LEGO® bricks engaging and useful.

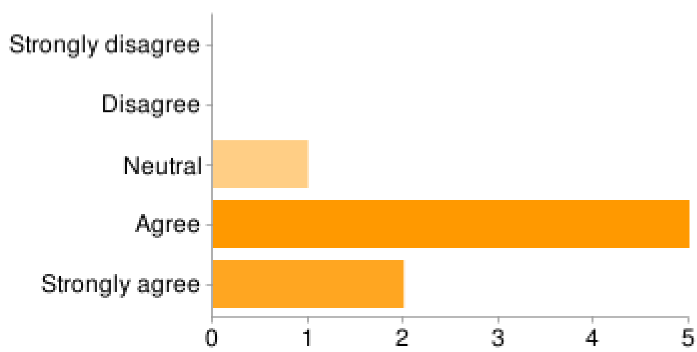

FIGURE 2: MY STUDENTS WOULD FIND WORKING WITH LEGO® BRICKS ENGAGING/USEFUL BREAKDOWN

Similarly, the respondents believed that the directions were written clearly and at an appropriate level for both the mechanical and programming sections.

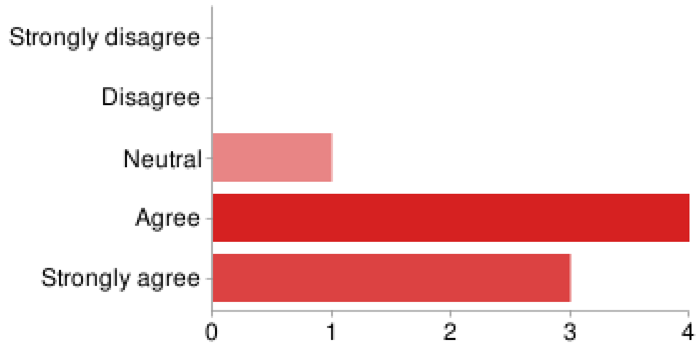

FIGURE 3: DIRECTIONS FOR STUDENTS ARE CLEARLY WRITTEN BREAKDOWN

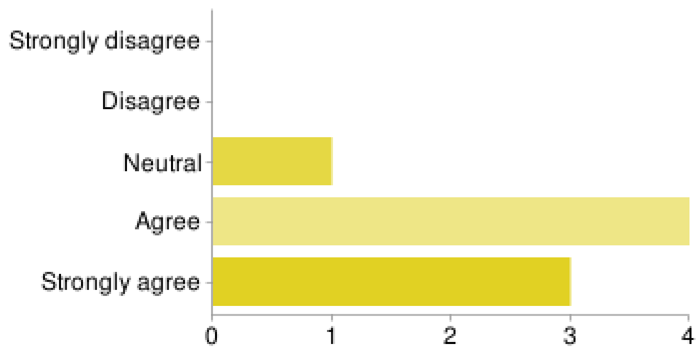

FIGURE 4: PROGRAMMING INSTRUCTIONS ARE CLEARLY PRESENTED BREAKDOWN

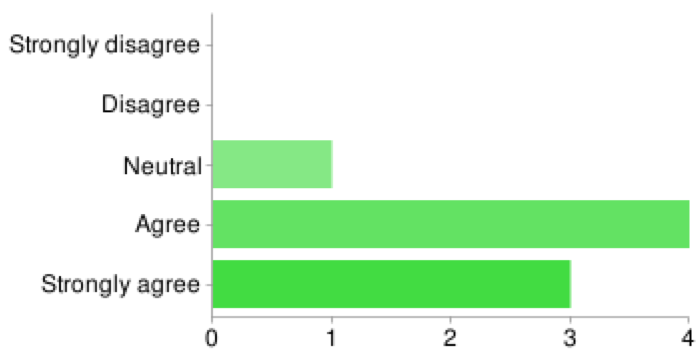

FIGURE 5: INSTRUCTION IS AT A LEVEL APPROPRIATE FOR MY STUDENTS BREAKDOWN

The majority of the teachers believe that their students could benefit from the instruction.

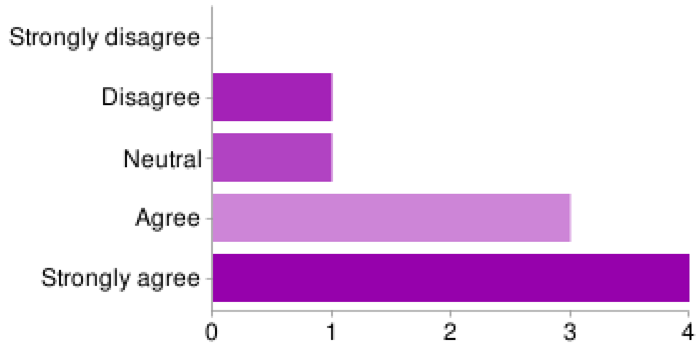

FIGURE 6: MY STUDENTS COULD BENEFIT FROM THIS TYPE OF INSTRUCTION BREAKDOWN

The respondents indicate that they believe that the material would be easy to use and understand from the instructor's point of view. Additionally, the respondents indicate that they approve of the format of the lessons.

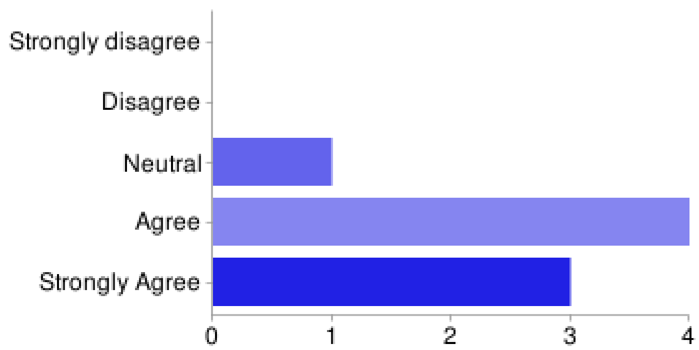

FIGURE 7: MATERIAL WOULD BE EASY TO USE BREAKDOWN

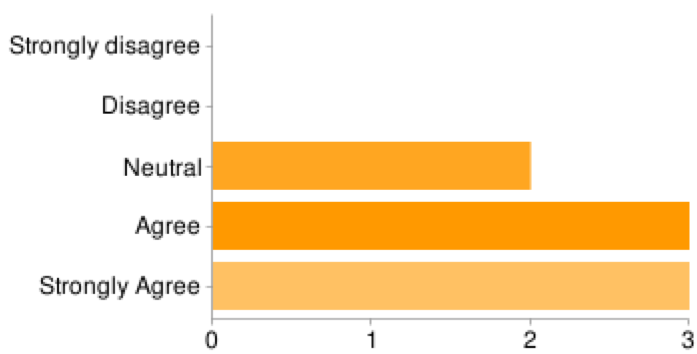

FIGURE 8: MATERIALS ARE EASY TO UNDERSTAND BREAKDOWN

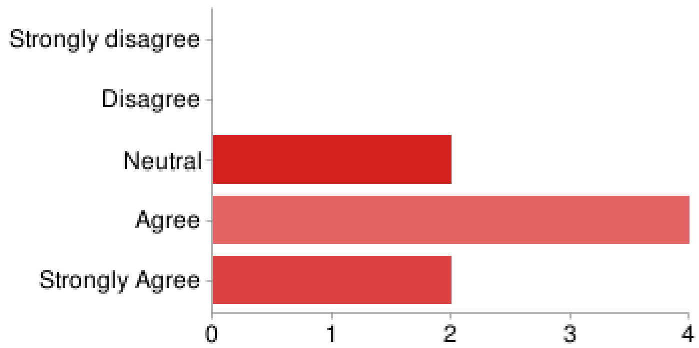

FIGURE 9: FORMAT/DESIGN OF LESSONS IS ONE I WOULD FEEL COMFORTABLE IN USING BREAKDOWN

The respondents varied more widely when asked whether the extent of the details in lesson plan was sufficient. The length of the lesson met with more approval.

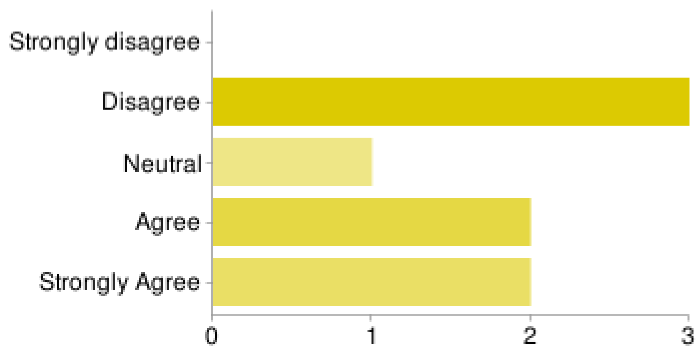

FIGURE 10: EXTENT OF DETAIL IN LESSON PLANS IS SUFFICIENT FOR ME

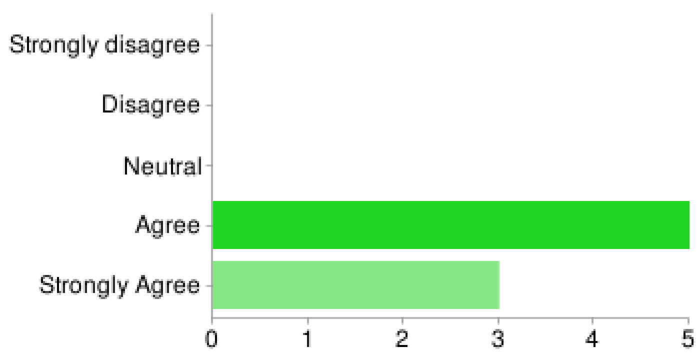

FIGURE 11: THE LENGTHS OF THE LESSONS SEEM APPROPRIATE BREAKDOWN

When value as an instructional tool of the different sections of the material was put in question, the response was universally positive.

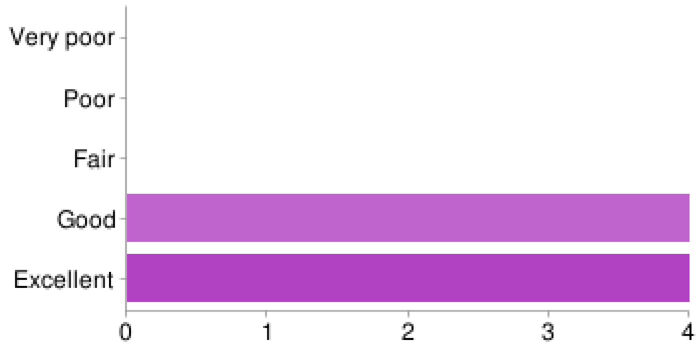

FIGURE 12: INSTRUCTION TO STUDENTS BREAKDOWN

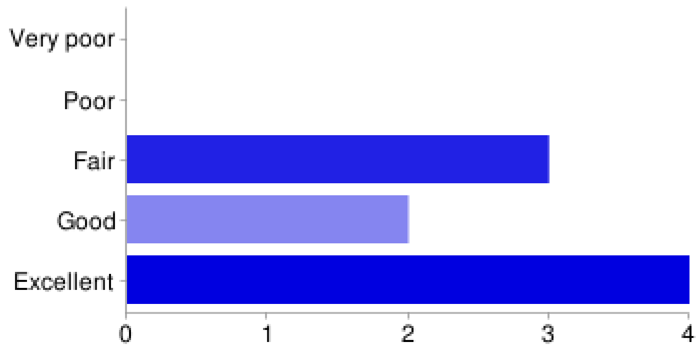

FIGURE 13: DEFINITIONS BREAKDOWN

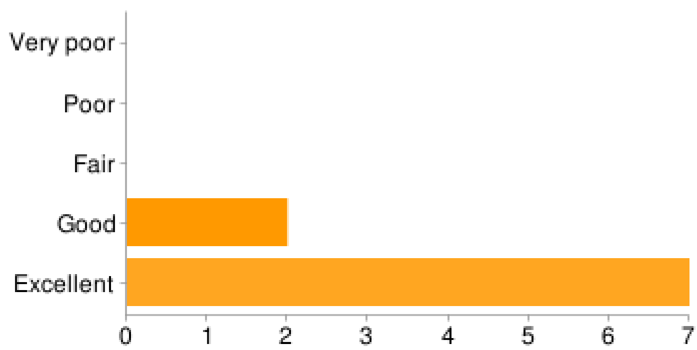

FIGURE 14: VIDEOS BREAKDOWN

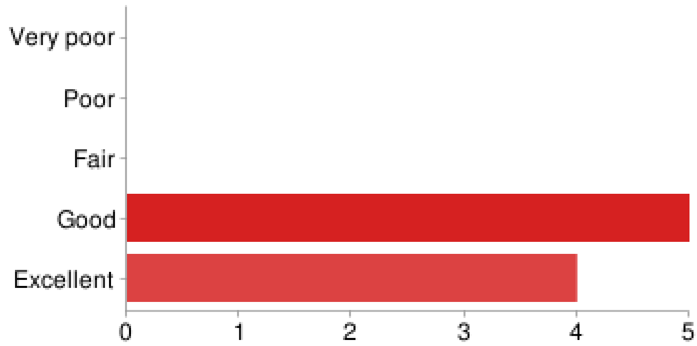

FIGURE 15: LEGO® BRICKS BREAKDOWN

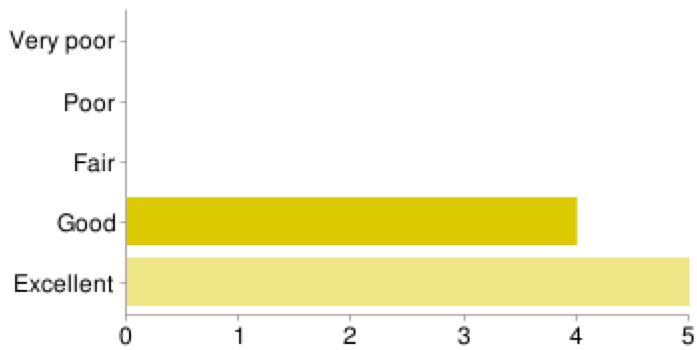

FIGURE 16: WORKSHEETS BREAKDOWN

The next subject asked about was if the curriculum should include more or less of the different sections of each lesson. For this, the amount of instruction for the students, definitions, and videos seemed to be appropriate. The majority of respondents requested additional instructor preparation material and worksheets.

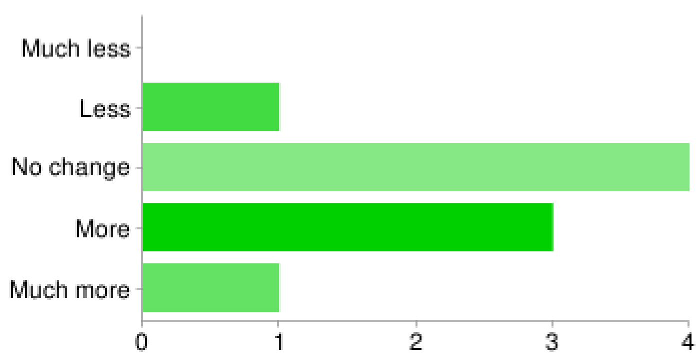

FIGURE 17: INSTRUCTION TO STUDENTS BREAKDOWN

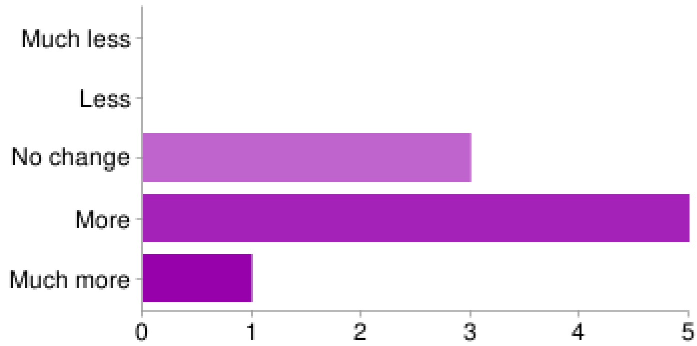

FIGURE 18: INSTRUCTOR PREPARATION MATERIAL BREAKDOWN

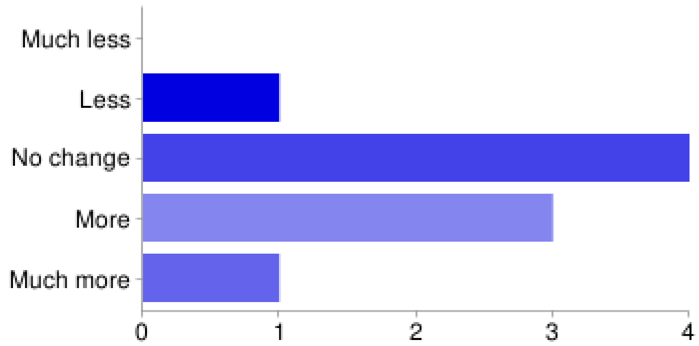

FIGURE 19: DEFINITIONS BREAKDOWN

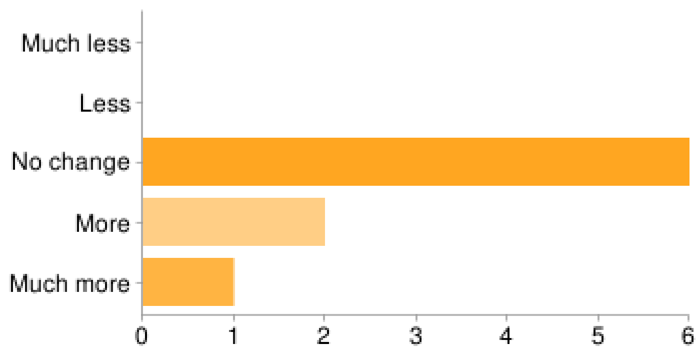

FIGURE 20: VIDEOS BREAKDOWN

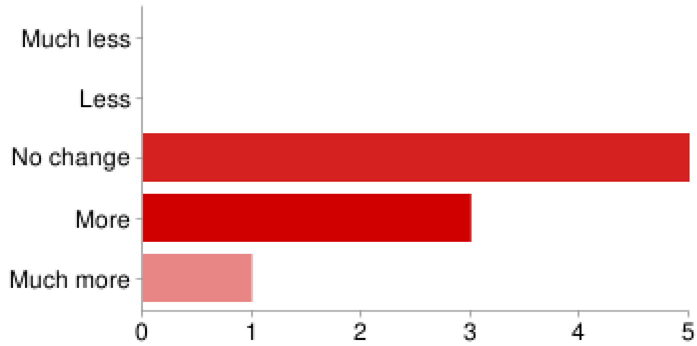

FIGURE 21: WORKSHEETS BREAKDOWN

The majority of respondents believed that an instructor without a teaching background could use the material.

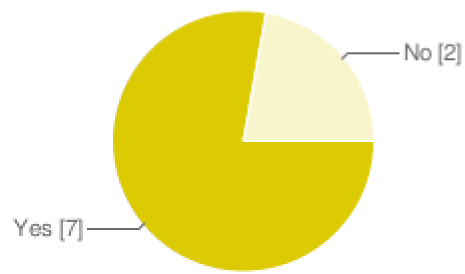

FIGURE 22: DO YOU THINK THAT LESSON MATERIALS LIKE THIS COULD BE USED IN AN AFTER-SCHOOL PROGRAM WITH AN INSTRUCTOR WHO DOES NOT NECESSARILY HAVE A TEACHING BACKGROUND? BREAKDOWN

The respondents indicate that more background information would be helpful to make the program more appropriate for an after-school program.

In general, the respondents indicated that having more than one instructor would be beneficial.

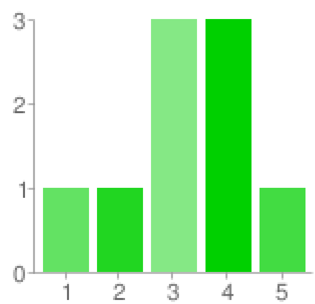

FIGURE 23: HOW MUCH DO YOU THINK A CLASS BASED AROUND THIS CURRICULUM WOULD BENEFIT FROM HAVING MORE THAN A SINGLE INSTRUCTOR IN THE CLASSROOM? BREAKDOWN

15 students is the approximate number that the respondents thought that one teacher could effectively use the material with.

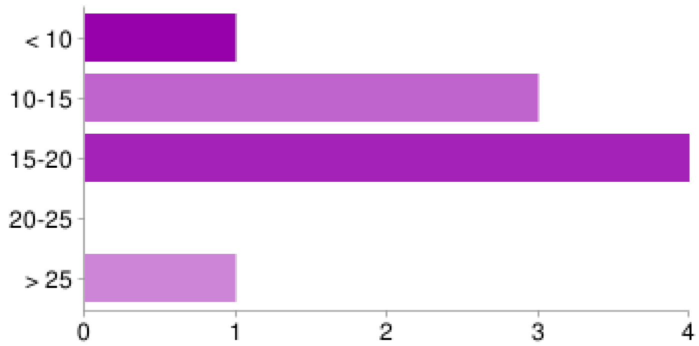

FIGURE 24: WHAT MAXIMUM NUMBER OF STUDENTS PER TEACHER DO YOU THINK COULD BE USED WITH THIS MATERIAL? BREAKDOWN

The majority of respondents indicate that they believe that the methods of testing the student's mastery are effective.

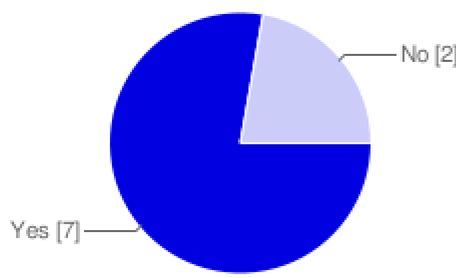

FIGURE 25: DO YOU THINK THE PROPOSED EVALUATION METHODS WOULD BE EFFECTIVE FOR DISCERNING THE STUDENTS' MASTERY OF THE MATERIAL? BREAKDOWN

The durability of the LEGO® bricks was confirmed by the respondents although there were concerns about parts being lost.

CONCLUSIONS AND RECOMMENDATIONS

It is clear from the research and responses that we have received, that we are developing a viable curriculum that would successfully introduce middle school-aged students to the concepts outlined in the RoboKids curriculum. The majority of the responses were favorable to both content of the program and the methodology of introducing the information. The authors have received requests from the reviewers for our materials with the expectation that they could pilot it for their school. This would be important and needed to direct further refinements. The authors recognize that this project is only the beginning and that further work will be required by future WPI students. Nevertheless, we are optimistic that our approach will give both teachers and volunteers the confidence they will need to implement such a program in their school.

There are a number of ways that this set of lessons might be improved, such as adding more lessons, adding detail to the existing lessons, including design in more of the lessons, and adding assignments. Adding additional lessons would allow for a wider array of topics to be addressed as well as being able to go in to more depth on the existing subjects. Moving the design section of the lessons out from the final project would allow for more information about design to be imparted to the students. Assignments would allow for teachers to have a better idea of what their students are learning and to have students use what they have learned in class.

With additional lessons more detail could be added to the programming section of the curriculum in particular, which currently only goes over some of the basic programming concepts. Additional lessons on programming would allow for students to create their own programs as well as those that are walked through in the lessons. This would also allow for programs to be created that would more effectively demonstrate some of the uses of the different sensors. The additional lessons could also be used to add material on completely new subjects such as lever arms or linkages. These additional lessons would follow much the same format as the gears lesson, having an introductory video that explains about the concept and how it can be used. After this video there would be an in-class project to give a hands-on demonstration of the material.

The current set of lessons has the students building very specific devices and programs. While this allows teachers to easily identify what is wrong with a system, it does not help in developing the problem solving skills of the students. In order to maintain the current layout of the lessons, small projects could be added throughout the curriculum where students design mechanical devices in addition to their own programs. These projects would help to teach problem solving methods.

The curriculum currently does not have any homework assignments. The creation and inclusion of that kind of material might give teachers a more accurate method to grade the students. Adding assignments like that would also mean that students would have to apply what the learned in the classes. In addition to the possibility of homework assignment, presentations could also be used as an effective method of evaluation. These presentations, as noted in the observations section, should be included as options for an extended program in future versions of the curriculum.

The initial survey that was created indicates that the material that has been created is relatively well constructed but additional material is required. The respondents indicated that they would find more background information valuable. This background information would include instructor resources and definitions of terminology. The instructor resources would include more background information on the material for each lesson such as more detailed information about how to use and space gears. Another example of additional teacher background for Unit 1, Lesson 1 would be a more extensive list of devices that the students might come up with and information about why they are or are not robots. Additionally, the curriculum could identify locations to acquire more information on the robots that are mentioned in the video.

We also recommend that reading the article entitled "An Effective Standards-Based K-12 Science and Technology/Engineering Classroom" be incorporated in the training of future RoboKids instructors in particular.

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(http://www.sciencedirect.com/science/article/B6VCJ-4JF8H6N-1/2/8d82c6d5be015315e2639e404a253cbc)

GLOSSARY

Actuator

Any part of a robot that creates motion. For example, the motors in the NXT kit are actuators.

Effector

An arm or other device, such as the wheels of the robot, which the robot can use to affect its environment in some way

Gear Ratio

The number of teeth on one gear, compared to the number of teeth on another. This comparison defines whether you are 'gearing up' (faster output, less torque) or 'gearing down' (slower output, more torque)

Program Block

The basic unit for building programs for the LEGO® MINDSTORMS® controller

Parameters

The data that controls how each programming block works

Robot

A device that takes in information, processes it, and takes action based on those results.

Sensor

A device that relays some information about the environment to the robot

Torque

A turning or twisting force. This is the force that will move an actuator around a pivot

APPENDIX

FIRST RESPONSE

Timestamp

4/26/2010 7:46:12

Type of school

Public, High

Grades and subjects taught

Computer Science 9-12

AP Computer Science 10-12

Robotics Club Sponsor (Botball)

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

No response

Information about students' viewpoint [Directions for students are clearly written]

No response

Information about students' viewpoint [Programming instructions are clearly presented]

No response

Information about students' viewpoint [Instruction is at a level appropriate for my students]

No response

Information about students' viewpoint [My students could benefit from this type of instruction]

Strongly agree

Information about teacher's viewpoint [Material would be easy to use]

No response

Information about teacher's viewpoint [Materials are easy to understand]

No response

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

No response

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

No response

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

No response

Value as an instructional tool [Instruction to students]

Excellent

Value as an instructional tool [Definitions]

Excellent

Value as an instructional tool [Videos]

Excellent

Value as an instructional tool [LEGO® bricks]

Good

Value as an instructional tool [Worksheets]

Excellent

An optimum lesson package would include more or less of which components? [Instructions to students]

No change

An optimum lesson package would include more or less of which components? [Instructor preparation material]

More

An optimum lesson package would include more or less of which components? [Definitions]

No change

An optimum lesson package would include more or less of which components? [Videos]

More

An optimum lesson package would include more or less of which components? [Worksheets]

More

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

Yes

What could be modified to make this material more appropriate for an after-school program?

I would love to see the rest of the materials. I would be able to use this after school. The lessons seem self explanatory. As we are preparing for the botball tournament, the Mindstorms program is not useful for us. We use a modified version of C. There is even a simulator to test to programs. Perhaps the programs could be provided in that language as well.

The units could be used from September to February to prepare the team for the actual challenge.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

4/5

What maximum number of students per teacher do you think could be used with this material?

15-20

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

Yes

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

I have found that even though I organize all the pieces at the start of a season, by the end they are all over the place. A teacher or organizer needs to keep up with the parts if they expect them to last.

Please provide any additional comments that you might have.

I loved lesson 2.4. The videos were an excellent way to have students see the concept in action. Teachers will not have time to build the all the robots to present the lesson.

I would have liked to see a robot actually move in the videos in lesson 1.3. The explanation was good but hard to visualize if you have never used Mindstorms.

Timestamp

4/27/2010 8:10:15

Type of school

High

Grades and subjects taught

Algebra I

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Agree

Information about students' viewpoint [Directions for students are clearly written]

Neutral

Information about students' viewpoint [Programming instructions are clearly presented]

Neutral

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Neutral

Information about students' viewpoint [My students could benefit from this type of instruction]

Neutral

Information about teacher's viewpoint [Material would be easy to use]

Agree

Information about teacher's viewpoint [Materials are easy to understand]

Neutral

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Neutral

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Disagree

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Agree

Value as an instructional tool [Instruction to students]

Good

Value as an instructional tool [Definitions]

Fair

Value as an instructional tool [Videos]

Good

Value as an instructional tool [LEGO® bricks]

Good

Value as an instructional tool [Worksheets]

Good

An optimum lesson package would include more or less of which components? [Instructions to students]

More

An optimum lesson package would include more or less of which components? [Instructor preparation material]

More

An optimum lesson package would include more or less of which components? [Definitions]

More

An optimum lesson package would include more or less of which components? [Videos]

No change

An optimum lesson package would include more or less of which components? [Worksheets]

No change

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

No

What could be modified to make this material more appropriate for an after-school program?

I know that this material is a piece of the entire whole. I am assuming that the students have been taught about gears previously to using this material. If not, they will be confused as to why you do what you do in the first set of videos.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

1/5

What maximum number of students per teacher do you think could be used with this material?

10-15

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

Yes

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

It should hold up provided the students treated all the material with respect.

Please provide any additional comments that you might have.

If this material is taken from a larger group of material, I would need to see the information that is provided as a lead-up to this material.

Timestamp

4/27/2010 9:33:59

Type of school

High

Grades and subjects taught

9-11, ESOL

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Agree

Information about students' viewpoint [Directions for students are clearly written]

Agree

Information about students' viewpoint [Programming instructions are clearly presented]

Agree

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Agree

Information about students' viewpoint [My students could benefit from this type of instruction]

Agree

Information about teacher's viewpoint [Material would be easy to use]

Agree

Information about teacher's viewpoint [Materials are easy to understand]

Neutral

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Agree

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Agree

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Agree

Value as an instructional tool [Instruction to students]

No response

Value as an instructional tool [Definitions]

Fair

Value as an instructional tool [Videos]

Good

Value as an instructional tool [LEGO® bricks]

Good

Value as an instructional tool [Worksheets]

Good

An optimum lesson package would include more or less of which components? [Instructions to students]

Less

An optimum lesson package would include more or less of which components? [Instructor preparation material]

No change

An optimum lesson package would include more or less of which components? [Definitions]

Less

An optimum lesson package would include more or less of which components? [Videos]

No change

An optimum lesson package would include more or less of which components? [Worksheets]

No change

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

Yes

What could be modified to make this material more appropriate for an after-school program?

Include materials for more practice.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

4/5

What maximum number of students per teacher do you think could be used with this material?

15-20

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

Yes

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

I teach ESOL students, who do have some issues with vocabulary and comprehension. They need more time to decode the information and make inferences.

Please provide any additional comments that you might have.

I think the lesson plans will be beneficial for regular education students.

Timestamp

4/27/2010 22:40:36

Type of school

High, Suburban

Grades and subjects taught

9th -12th World of Technology, principle of engineering, material processing, construction systems

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Agree

Information about students' viewpoint [Directions for students are clearly written]

Strongly agree

Information about students' viewpoint [Programming instructions are clearly presented]

Strongly agree

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Strongly agree

Information about students' viewpoint [My students could benefit from this type of instruction]

Strongly agree

Information about teacher's viewpoint [Material would be easy to use]

Strongly Agree

Information about teacher's viewpoint [Materials are easy to understand]

Strongly Agree

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Agree

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Agree

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Strongly Agree

Value as an instructional tool [Instruction to students]

Excellent

Value as an instructional tool [Definitions]

Excellent

Value as an instructional tool [Videos]

Excellent

Value as an instructional tool [LEGO® bricks]

Excellent

Value as an instructional tool [Worksheets]

Excellent

An optimum lesson package would include more or less of which components? [Instructions to students]

No change

An optimum lesson package would include more or less of which components? [Instructor preparation material]

No change

An optimum lesson package would include more or less of which components? [Definitions]

No change

An optimum lesson package would include more or less of which components? [Videos]

More

An optimum lesson package would include more or less of which components? [Worksheets]

More

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

No

What could be modified to make this material more appropriate for an after-school program?

More background information to help instructors to understand the material more. Also more examples to show the teacher and student to understand the materials.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

4/5

What maximum number of students per teacher do you think could be used with this material?

10-15

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

Yes

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

Very well.

Please provide any additional comments that you might have.

No response

Timestamp

4/28/2010 6:34:53

Type of school

Public, Middle/Secondary, Suburban

Grades and subjects taught

Honors Precalculus with Trig, AP Calculus BC, Multivariable Calculus, Linear Algebra

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Neutral

Information about students' viewpoint [Directions for students are clearly written]

Agree

Information about students' viewpoint [Programming instructions are clearly presented]

Agree

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Agree

Information about students' viewpoint [My students could benefit from this type of instruction]

Agree

Information about teacher's viewpoint [Material would be easy to use]

Neutral

Information about teacher's viewpoint [Materials are easy to understand]

Agree

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Agree

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Disagree

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Agree

Value as an instructional tool [Instruction to students]

Good

Value as an instructional tool [Definitions]

Fair

Value as an instructional tool [Videos]

Excellent

Value as an instructional tool [LEGO® bricks]

Good

Value as an instructional tool [Worksheets]

Excellent

An optimum lesson package would include more or less of which components? [Instructions to students]

More

An optimum lesson package would include more or less of which components? [Instructor preparation material]

More

An optimum lesson package would include more or less of which components? [Definitions]

More

An optimum lesson package would include more or less of which components? [Videos]

No change

An optimum lesson package would include more or less of which components? [Worksheets]

No change

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

Yes

What could be modified to make this material more appropriate for an after-school program?

Many of my responses above were influenced by the fact that I had never seen the software, know nothing about robotics. I'm hoping lessons 1.1 and 1.2 contain definitions and descriptions of the software and what the blocks do, what the options at the bottom of the software mean. If that is true, many of my answers above would be different.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

3/5

What maximum number of students per teacher do you think could be used with this material?

15-20

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

Yes

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

I teach upper-level students. I think they would respect the parts. Middle school students would be throwing them around the room!

Please provide any additional comments that you might have.

The number of instructors would depend on the number of students. Above answers assume 25 students.

Timestamp

4/28/2010 12:26:30

Type of school

Public

Grades and subjects taught

11, 12 - Oracle, Web Page Development

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Agree

Information about students' viewpoint [Directions for students are clearly written]

Agree

Information about students' viewpoint [Programming instructions are clearly presented]

Agree

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Strongly agree

Information about students' viewpoint [My students could benefit from this type of instruction]

Disagree

Information about teacher's viewpoint [Material would be easy to use]

Agree

Information about teacher's viewpoint [Materials are easy to understand]

Agree

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Neutral

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Disagree

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Agree

Value as an instructional tool [Instruction to students]

Good

Value as an instructional tool [Definitions]

Good

Value as an instructional tool [Videos]

Excellent

Value as an instructional tool [LEGO® bricks]

Good

Value as an instructional tool [Worksheets]

Good

An optimum lesson package would include more or less of which components? [Instructions to students]

More

An optimum lesson package would include more or less of which components? [Instructor preparation material]

More

An optimum lesson package would include more or less of which components? [Definitions]

No change

An optimum lesson package would include more or less of which components? [Videos]

No change

An optimum lesson package would include more or less of which components? [Worksheets]

No change

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

Yes

What could be modified to make this material more appropriate for an after-school program?

No response

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

3/5

What maximum number of students per teacher do you think could be used with this material?

15-20

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

Yes

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

My students are old enough to not lose the parts. They would hold up fine.

Please provide any additional comments that you might have.

No response

Timestamp

4/28/2010 18:49:08

Type of school

Public

Grades and subjects taught

9-12 Honors Geometry & Algebra 2

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Agree

Information about students' viewpoint [Directions for students are clearly written]

Agree

Information about students' viewpoint [Programming instructions are clearly presented]

Agree

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Agree

Information about students' viewpoint [My students could benefit from this type of instruction]

Agree

Information about teacher's viewpoint [Material would be easy to use]

Agree

Information about teacher's viewpoint [Materials are easy to understand]

Agree

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Agree

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Neutral

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Agree

Value as an instructional tool [Instruction to students]

Good

Value as an instructional tool [Definitions]

Good

Value as an instructional tool [Videos]

Excellent

Value as an instructional tool [LEGO® bricks]

Excellent

Value as an instructional tool [Worksheets]

Excellent

An optimum lesson package would include more or less of which components? [Instructions to students]

No change

An optimum lesson package would include more or less of which components? [Instructor preparation material]

More

An optimum lesson package would include more or less of which components? [Definitions]

No change

An optimum lesson package would include more or less of which components? [Videos]

No change

An optimum lesson package would include more or less of which components? [Worksheets]

No change

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

Yes

What could be modified to make this material more appropriate for an after-school program?

I don't think it would need modifying.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

3/5

What maximum number of students per teacher do you think could be used with this material?

10-15

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

No

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

Legos usually hold up.

Please provide any additional comments that you might have.

No response

EIGHTH RESPONSE

Timestamp

4/29/2010 8:33:37

Type of school

Public

Grades and subjects taught

9, 10, 11, precalculus and accelerated computer science

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Strongly agree

Information about students' viewpoint [Directions for students are clearly written]

Strongly agree

Information about students' viewpoint [Programming instructions are clearly presented]

Strongly agree

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Strongly agree

Information about students' viewpoint [My students could benefit from this type of instruction]

Strongly agree

Information about teacher's viewpoint [Material would be easy to use]

Strongly Agree

Information about teacher's viewpoint [Materials are easy to understand]

Strongly Agree

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Strongly Agree

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Strongly Agree

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Strongly Agree

Value as an instructional tool [Instruction to students]

Excellent

Value as an instructional tool [Definitions]

Excellent

Value as an instructional tool [Videos]

Excellent

Value as an instructional tool [LEGO® bricks]

Excellent

Value as an instructional tool [Worksheets]

Excellent

An optimum lesson package would include more or less of which components? [Instructions to students]

Much more

An optimum lesson package would include more or less of which components? [Instructor preparation material]

Much more

An optimum lesson package would include more or less of which components? [Definitions]

Much more

An optimum lesson package would include more or less of which components? [Videos]

Much more

An optimum lesson package would include more or less of which components? [Worksheets]

Much more

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

Yes

What could be modified to make this material more appropriate for an after-school program?

This seems like an engaging and worthwhile project as it is.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

2/5

What maximum number of students per teacher do you think could be used with this material?

> 25

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

Yes

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

The stuff seems pretty durable

Please provide any additional comments that you might have.

I would enjoy doing the assignments myself. I think kids (both girls and boys) would also enjoy the assignments.

Timestamp

5/2/2010 12:17:21

Type of school

Public

Grades and subjects taught

9-12, Mathematics

Information about students' viewpoint [My students would find working with LEGO® bricks engaging/useful]

Strongly agree

Information about students' viewpoint [Directions for students are clearly written]

Strongly agree

Information about students' viewpoint [Programming instructions are clearly presented]

Strongly agree

Information about students' viewpoint [Instruction is at a level appropriate for my students]

Agree

Information about students' viewpoint [My students could benefit from this type of instruction]

Strongly agree

Information about teacher's viewpoint [Material would be easy to use]

Strongly Agree

Information about teacher's viewpoint [Materials are easy to understand]

Strongly Agree

Information about teacher's viewpoint [Format/design of lessons is one I would feel comfortable in using]

Strongly Agree

Information about teacher's viewpoint [Extent of detail in lesson plans is sufficient for me]

Strongly Agree

Information about teacher's viewpoint [The lengths of the lessons seem appropriate]

Strongly Agree

Value as an instructional tool [Instruction to students]

Excellent

Value as an instructional tool [Definitions]

Excellent

Value as an instructional tool [Videos]

Excellent

Value as an instructional tool [LEGO® bricks]

Excellent

Value as an instructional tool [Worksheets]

Good

An optimum lesson package would include more or less of which components? [Instructions to students]

No change

An optimum lesson package would include more or less of which components? [Instructor preparation material]

No change

An optimum lesson package would include more or less of which components? [Definitions]

More

An optimum lesson package would include more or less of which components? [Videos]

No change

An optimum lesson package would include more or less of which components? [Worksheets]

More

Do you think that lesson material like this could be used in an after-school program with an instructor who does not necessarily have a teaching background?

Yes

What could be modified to make this material more appropriate for an after-school program?

A buddy system would be good. Have enough students on hand to help beginners.

How much do you think a class based around this curriculum would benefit from having more than a single instructor in the classroom?

5/5

What maximum number of students per teacher do you think could be used with this material?

< 10

Do you think the proposed evaluation methods would be effective for discerning the students' mastery of the material?

No

How do you think the hardware associate with this curriculum would hold up to your students with respect to durability and lost parts?

It would hold up. Hopefully it wouldn't start to disappear.

Please provide any additional comments that you might have.

I thought the worksheet was too easy and questioned the ratio answers. EX: Ratios asked for red to blue had an answer reflecting the ratio of blue to red. Both ratio questions were answered in reverse--unless I misunderstood the question.