Robotics and the Engineering Design Process and its Influence on Student Achievement and Motivation in Middle School STEM (Science, Technology, Engineering, and Math) Related Concepts

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Abstract

Much research is needed to verify positive educational outcomes using robotics and the engineering design process, to improve student concept attainment, motivation and interest in the areas of science, technology, engineering, and math. My main research question was, "In what ways do robotics and the engineering design process affect student achievement and motivation involving STEM (**S**cience, **T**echnology, **E**ngineering, and **M**ath) at the middle school level?"

- Do robotics and the engineering design process play a positive influence on student achievement and motivation in STEM related concepts at the middle school level?
- How well can students document their thinking, in order to share the process they went through to solve a given design challenge?
- When a student uses a "hands on, minds on, inquiry-based" activity format, will the student will be able to understand academic concepts at a deeper level, when learned in context to the real world?
- Does the engineering and design process create engaged students, intrinsically motivated to learn by the desire to understand how and why something works, rather than be assigned something to learn?
- How can I be the catalyst in my school district for changing the way we think and teach science topics to youngsters?

I want to find ways to convince others of the need for more STEM type activities in our learning plans for students. I truly want to be the catalyst in my school district for changing the way we think and teach science topics to youngsters.

Keywords:

STEM (**S**cience, **T**echnology, **E**ngineering, and **M**ath)

P21 (Partnership for 21st Century Skills)

Tech Ed. (Technology Education)

SPIRIT (Silicon Prairie Initiative for Robotics in Information Technology)

ISTE (International Society for Technology in Education)

NETS (National Educational Technology Standards)

Robotics and the Engineering Design Process and its Influence on

Student Achievement and Motivation in Middle School STEM

(**S**cience, **T**echnology, **E**ngineering, and **M**ath) Related Concepts

To date little effort has been made to define the content of K-12 engineering in a rigorous or systematic way. I am interested in finding out how the engineering and design process can be used as a context for exploring science, technology, and mathematics concepts to promote engineering habits of mind. I am most interested in finding out how science inquiry and mathematical reasoning can be connected to engineering design, in K-12 curricula and teacher professional development.

By studying robotics, students gain a deeper understanding of complex topics and realize a purpose for content knowledge taught in the academic disciplines of physics, computer science, engineering, and mathematics. Robots appeal to a broad range of students and allow multiple points of access to science and technology for many types of learners. While studying robotics, students acquire hands-on experience in design, construction, and problem solving, and encounter the important relationship between science and technology. Students are motivated to learn by creating their own robotic devices, while at the same time gaining a deeper under-standing of the interdisciplinary fields of study mentioned above.

I wanted to investigate the premise that when a student uses a “hands on, minds on, inquiry-based” activity format, the student will be able to understand several academic concepts being taught, at a deeper level, when learned in context to the real world. I hope that my data can further support the findings of previous researchers in this field of study. The Committee on K-12 Engineering Education, from the National Academy of Engineering and the National

Research Council (2009) noted that when a school subject is taught, there should be a conceptual connection to post-secondary studies, and to the practice of that subject in the real world.

The question I investigated was, "In what ways do robotics and the engineering design process affect student achievement and motivation involving STEM (**S**cience, **T**echnology, **E**ngineering, and **M**ath) at the middle school level?" In reviewing the body of current research on this subject, I consulted various reports and journal articles on the subject and worked to synthesize all the information previous scholars had done, in order to help guide my quest for the answer to my main question, and list of related questions.

First, I will present the findings of several researchers that have previously studied the topics of robotics and / or the engineering design process. Next, I will provide some background of the context I used for my investigation. Following the data collection explanations, I will discuss methods used to analyze the data. Next I will present the findings as related to my research, and last I will discuss the importance of the findings and where I think my quest needs to go next.

Literature Review

When students design, build, and program an autonomous robot, they are exposed to advanced math, science, and technology concepts. Robotics can be integrated into many academic disciplines. As students make cross disciplinary connections, they will synthesize new knowledge for themselves, and begin to understand how science and technology control the world in which they live. Robin Shoop (2005) stated that an engaged student, **intrinsically** motivated to learn, and moved by a desire to understand how and why something works will learn better than one **assigned** something to learn. He noted that the desire for competence and understanding stimulates the learning process.

In 2008 the La Vista Junior High agreed to target problem solving as their building goal, because they wanted to focus on helping students increase their independent problem solving skills in both academic and social contexts. Each department developed problem solving processes involving the following steps, tailored to each particular department's needs:

- Understand the problem
- Develop a plan
- Solve the problem
- Evaluate and reflect

As a part of the 2009-10 classroom goals, teachers were encouraged to set goals incorporating the problem solving steps appropriate for their students. Teachers were expected to intentionally teach explicit structures and styles of problem solving, in order to provide students with the knowledge and skills they would need to solve problems in all academic areas, and within their social contexts.

Specific questions were developed by the School Improvement Team to guide staff in the attainment of the problem solving goal discussed above. The team hoped to focus on the following questions for the school year:

1. *How can we support instruction that focuses on conceptual understanding?*
2. *What are we doing to enhance and insure equity of learning experiences for all students?*
3. *What can be done to encourage teachers to emphasize the "how" and "why" over the "what" of instruction?*
4. *What can be done to address teachers' skepticism about best practices in instruction?*
5. *How can we foster teachers' development of higher level questioning and scaffolding for student learning?*

I am intrigued by the fact that the engineering design process is indeed one way to institute the problem solving process with students. I have found the design process becomes a motivational way, to get students to problem solve, and excited to accomplish the challenge presented to them.

I have organized Camp Invention activities for students in my surrounding community since the summer of 2008, which involves students investigating scientific concepts. Students become very involved in inquiry based activities and enjoy all the thinking and investigating they are expected to do during each of the five stations they visit for the five days of camp. This camp has become a very popular program and has changed the way a lot of students and teachers view science learning. It is one of two experiences that really changed the way I look at the science, technology, and mathematics we need to be exposing our students to.   A supervisor from the curriculum office came to observe the camp the first summer, and mentioned how cool the events were. He specifically asked, “Why can’t we be doing this kind of thing everyday during the school year?” I agreed with him, but also know how easy it is to get tied down to “the curriculum that must be TAUGHT”. It is very difficult for many teachers to allow students to play around with ideas and concepts, and pose questions to them effectively in order to help students form an understanding that is accurate. Most teachers just want to help the students get to the right answer.

In July of 2008, I worked with engineers from the University of Nebraska Lincoln and the Peter Kiewit Institute, and professors of education at the University of Nebraska at Omaha with the SPIRIT project, a National Science Foundation Grant. The university faculty brought to the attention of all workshop participants, the need for educators to prepare students for the possibility of pursuing an engineering career. The shortage of people that will be qualified for engineering positions in the next few years was presented to us, and was quite alarming to us all. Throughout the two weeks of the workshop, I was fascinated with the chance to have my hands involved with electronics and mechanical concepts I had never previously experienced. Since that time I have been involved with several activities connected with UNO and the Peter Kiewit Institute, involving students in robotics and engineering activities. Kids today are very intuitive and given the opportunity, can figure out most anything, if we just step aside and allow them to work.

In the fall semester of 2008, sixth grade students were very excited by the engineering challenges I put in front of them the first few months of the school year. At first they would look to me for suggestions about how to solve the challenge. When I only referred them back to the design problem and exact wording, they had to “go back to the drawing board” and try to figure out what might possibly be the answer. They had no choice, but to figure it out, as I told them I was only presented with the problem from my teacher guide, and had no way of telling them what the answer could or should look like. I was always pleased to hear from the classroom teacher the following week that students had been begging all week long, to work to improve their design solutions, whenever they had time, in order to make their solution better. Students were excited to share their designs with me at the next weekly meeting.

Since the summer of 2008, I have a new fire in me to help bring the excitement of inquiry based teaching in math, science, and technology, as well as engineering design principles, into the hands of more educators, so our students can aspire to be the most creative and best problem solvers in the world, rather than falling further and further behind other countries, due to educators lack of motivating and guiding them to think futuristically. I want to find ways to convince others of the need for more STEM type activities in our learning plans for students. I truly want to be the catalyst in my school district for changing the way we think and teach science topics to youngsters. In January of 2009, I was awarded a grant from my local school foundation to fund Lego Mindstorm Robotics Kits and software to use with sixth graders in my two elementary schools.

Since I moved to the junior high in the fall of 2009, others had to find ways to present the robotics experiences to our elementary students. A high ability learner seminar was offered to fifth and sixth grade students beginning in the fall of 2009. I worked with the educator that presented the course, to help plan out the activities to be presented in the two day seminar. Several students across the district had robotics as their Gifted Education Plan goal. They worked all school year learning how to program the robots to complete certain tasks. In April of 2010, fourth through sixth grade students performed in a robotics competition in one of our elementary school gyms. Twenty teams of students participated and had their robots complete an autonomous course, gaining points for meeting various criteria, and losing points if their robot went outside the boundaries. I was amazed at how well the students in fourth, fifth, or sixth grade completed the tasks.

National Education Priorities

The ISTE National Education Technology Standards and Performance Indicators for Students were published in 2007 (updated from 1998). Three years later, we still have a long way to go to get the outcomes suggested to become reality in most school systems around the country. The standards and performance indicators provide us with a framework to work toward.

The framework suggested for students emphasizes: creativity and innovation; communication and collaboration; research and information fluency; critical thinking, problem solving, and decision making; digital citizenship; and technology operations and concepts. The standards and performance indicators for teachers call for teachers to: facilitate and inspire student learning and creativity; design and develop digital-age learning experiences and assessments; model digital-age work and learning; promote and model digital-age citizenship and responsibility; and engage in professional growth and leadership. Figure 1 lists specific indicators for students to be able to do.

Figure 1

The* ISTE *National Educational Technology Standards (NETS•S) and

Performance Indicators for Students

1. Creativity and Innovation
Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology.
Students:
- *a. apply existing knowledge to generate new ideas, products, or processes.*
- *b. create original works as a means of personal or group expression.*
- *c. use models and simulations to explore complex systems and issues.*
- *d. identify trends and forecast possibilities.*

2. Communication and Collaboration
Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.
Students:
- *a. interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.*
- *b. communicate information and ideas effectively to multiple audiences using a variety of media and formats.*
- *c. develop cultural understanding and global awareness by engaging with learners of other cultures.*
- *d. contribute to project teams to produce original works or solve problems.*

3. Research and Information Fluency
Students apply digital tools to gather, evaluate, and use information.
Students:
- *a. plan strategies to guide inquiry.*
- *b. locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.*
- *c. evaluate and select information sources and digital tools based on the appropriateness to specific tasks.*
- *d. process data and report results.*

4. Critical Thinking, Problem Solving, and Decision Making
Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.

Students:

a. identify and define authentic problems and significant questions for investigation.

b. plan and manage activities to develop a solution or complete a project.

c. collect and analyze data to identify solutions and/or make informed decisions.

d. use multiple processes and diverse perspectives to explore alternative solutions.

5. Digital Citizenship

Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.

Students:

a. advocate and practice safe, legal, and responsible use of information and technology.

b. exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.

c. demonstrate personal responsibility for lifelong learning.

d. exhibit leadership for digital citizenship.

6. Technology Operations and Concepts

Students demonstrate a sound understanding of technology concepts, systems, and operations.

Students:

a. understand and use technology systems.

b. select and use applications effectively and productively.

c. troubleshoot systems and applications.

d. transfer current knowledge to learning of new technologies.

Several sources note the need for reform in today's educational setting, in order to prepare our students for the life they will lead when their education is completed. Many call for the necessity to address student needs with 21st Century processes and skills that are lacking in several of today's classrooms.

According to Blackboard K-12, Project Tomorrow, & Speak Up (2009), students have so much access to technology that they have become "free agent learners" and are less dependent upon traditional education institutions for knowledge acquisition. Students today, they note, are much more self reliant, using their technology skills to access information as they deem necessary. Students are learning how to live and adapt in an ever changing technological society. The study reports a widespread interest in online learning, but few opportunities for students to take courses that are developed as such. More than 40% of the 6th through 12th graders believed online classes should be part of an ideal school, yet only one in ten students have taken an online class through their school. Students stated that they wished to be in charge of their own learning. They expect online courses to be more accessible to success, since they can review materials when they want and at their own pace. Today's educators must decide whether we are going to adapt our courses to the digital age and expand learning opportunities for our students, or let the students continue to develop on their own, pursuing information, knowledge, and learning, without the support and guidance of professional educators.

Partnership for 21st Century Skills (2009) laid out a plan for student success in the new global economy. The *Framework for 21st Century Learning* presents the skills, knowledge and expertise students must attain in order to succeed in work and life (pg. 1). It is a blend of content knowledge, specific skills, expertise and understanding of several core literacies: *Global Awareness; Financial, Economic, Business and Entrepreneurial Literacy; Civic Literacy; Health Literacy; Environmental Literacy; Information Literacy; Media Literacy; and ICT (Information, Communications and Technology) Literacy*. The document further emphasizes the need for citizens and workers to exhibit a range of functional and critical thinking skills: *Flexibility and Adaptability; Initiative and Self-Direction; Social and Cross-Cultural Skills; Productivity and Accountability; Leadership and Responsibility.* P21, as they call themselves, provides tools and resources to help U.S. schools keep up, by fusing the three Rs and four Cs (critical thinking and problem solving, communication, collaboration, and creativity and innovation). They indicate that a strong support system must be in place to help students acquire the necessary skills needed to think critically and communicate effectively, based on core academic subject knowledge. The partnership points out the following five critical support systems needed to ensure student mastery of 21st Century Skills: *21st Century Standards; Assessments of 21st Century Skills; 21st Century Curriculum and Instruction; 21st Century Professional Development; 21st Century Learning Environments* (pg. 2).

P21 advocates for local, state and federal policies that support this approach for every school. They developed a guide in 2009 to help schools self assess and make the needed changes to prepare their students in the core academic areas, along with the four c(s): communication, critical thinking, creativity, and collaboration. The same skills needed with the four c(s) are found deeply embedded in engineering design challenges. Finding a new way to deliver instructional challenges to our students can foster the skills of critical thinking and problem solving, creativity and innovation, communication, and collaboration.

Scott Aronowitz (2010) noted The Partnership for 21st Century Skills group advocates project-based learning, as the most effective change that can be made to America's schools today. Enticing students to engage in rich learning projects, rooted in a real-world problem or question is deep, complex, rigorous, and integrated into all subject areas. Educators need to help students connect what they are learning, to the world around them, and find ways to solve real problems with the knowledge they gain throughout their educational careers. Problem-based learning involves teams of three or more students working together on an in-depth project for three to eight weeks. The project should be introduced through a complex question, establishing a student's need to know. The project unfolds through a scaffolding of activities along with new information that deepens the work. Planning the student work through plans, drafts, timely benchmarks, and ending with the team's presentation to an outside panel of experts from the field of work involved, along with parents and community members, makes the project even more realistic for the students. Timely assessments and feedback along the way concerning content, oral and written communication, teamwork, critical thinking, and other important skills, will help students polish up their project in order to prepare for an impressive presentation.

Aronowitz (2010) further noted that pushing students to become active in the community, looking for a problem to solve, and then thinking about possible solutions, will stoke student interest in something besides keeping up their grades and their social lives. Immediately collaboration, decision-making, and critical thinking are brought to the forefront in students' engaged minds. Further research investigating more about the problem, writing about their experiences, examining and analyzing their successes and their mistakes, increases the amount of real learning going on with the engaged students. Keeping a log of all their activities, progress, and any thoughts or ideas they might have, related to their work, makes the project even more real to them. The culmination of their work can be presented to an interested audience through a multimedia presentation. This type of work encompasses all components of the NETS standards, and better mirrors the work world of today's businesses.

In the spring of 2010, I had students participate in an Engineering Competition with the Peter Kiewit Institute. They worked to find a real problem to solve within their school or community, had to research the problem and possible solutions, and then come up with a final analysis and solution to present in late April to a group of engineers. This process mirrored what Aronowitz discussed, and seemed to support his beliefs and findings.

Other researchers note the importance of feedback from today's students in regards to how educators should design the learning environment for this new way of teaching and learning. Prensky (2006) stated that we can no longer use our 20th Century knowledge or training as a guide to what is best for today's students. Students today are native speakers of technology, fluent in the digital language of all their electronic devices. Our "pre digital accent" makes it difficult to communicate effectively with students today.

He suggested we regard student engagement as more important than content when teaching, and pay attention to how our students learn, finding out what they already know, and value and honor that knowledge. He further suggested encouraging students to take part in designing instructions, making decisions, and getting input from them about how they would teach a particular concept. We as educators must find a way to gather the information and knowledge students acquire outside of class in their daily digital lives, and connect it to what we are requiring them to do in school. Prensky (2006) noted that young people have a much better idea of the future than we do. We need to help our students take advantage of these new tools in order to educate themselves. We need to help students learn to adopt new systems for:

- Communicating
- Sharing
- Buying and Selling
- Exchanging
- Creating
- Meeting
- Collecting
- Coordinating
- Evaluating
- Searching
- Analyzing
- Learning (pg.10)

Prensky (2006) further suggested that we involve students in discussions about curriculum development, and all other aspects of educational decision making. He stated that our brightest students trusted with this responsibility will surprise us with all their contributions. They will be the best resource for suggesting better ways to do things, in order to get students to grasp particular concepts and skills (pg. 11). He noted that the educational environment needs to catch up with how to continually change, so each student can learn by having the educational tools adapt to every moment of an experience, according to a student's skill and knowledge level. Incorporating the combination of desirable goals, interesting choices, immediate and useful feedback, and opportunities to "level up" will engage kids, like their favorite complex computer and video games. Prensky (2006) further stated that digital technology within education will have its greatest effect on adaptability and connectivity. He urged educators to make use of students' cell phones, which could be one of the most important tools for 21st Century students. Since phones today are capable of so many things, one of the key skills necessary for kids today will be the ability to program, so that they can maximize the use of their tools by extending their programming capabilities (pg. 12).

Schools need to find a way to teach with technology and encourage students to use it as well. Students should know how to program, filter knowledge, and maximize the features and connectivity of their tools. Prensky (2006) noted that we need to listen to our students and value their opinions, making changes on the basis of their suggestions. If we do not comply we will be left with buildings to administer, but with students who are somewhere else, either physically or mentally (pg. 13).

I had the opportunity to work with UNO professors and students and teachers within the community, in mid April 2010, to serve as a focus group, to brainstorm how the renovation of a building to house the college of education might look, as we tried to brainstorm a plan that was "outside the box" of regular classroom design spaces. In less than two hours, middle school students and teachers thought of more than 100 ideas that were very futuristic minded. It was inspiring to listen to students' ideas and then piggyback on them, using our educational experience.

What is Known / Integration of Knowledge

Spires, Lee and Turner (2008) looked at how to best meet the needs of children living in a world filled with technological devices. They suggested we bridge the gap between how students live and learn. Students want to be engaged and stimulated in school through project based, discovery learning. They do not want to have to “unplug” themselves when they enter the school environment. They see a clear link between the use of technologies in school and their lesson engagement. Students want to use technology that is interactive and media oriented. They want school projects to relate to future careers they may have, and be encouraged to find new uses of technology they have available.

Students are calling for curriculum, instruction, and assessment that use 21st Century tools in the classroom (both hardware and software) with the connectivity and networks to create the interaction and access to information they need to use, in order to continue their learning. In order to keep pace with the students, there is a need for continued professional development of educators, so they will have the tools to encourage and support this type of learner.

The indicators suggested on the ISTE National Educational Technology Standards (NETS•S) and Performance Indicators for Students (2007) are very much in line with the engineering design processes that several authors suggest as the way to teach and engage our 21st Century students.

1. ***Creativity and Innovation***
2. ***Communication and Collaboration***
3. ***Research and Information Fluency***
4. ***Critical Thinking, Problem Solving, and Decision Making***
5. ***Digital Citizenship***
6. ***Technology Operations and Concepts*** (see Figure 1)

Katehi, Pearson, Feder (2007) in their work with the Committee on K-12 Engineering Education, noted that K-12 engineering education should emphasize the design process, be incorporated into important and developmentally appropriate mathematics, science, and technology skills, and promote engineering habits of mind: systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations (pg.4-5).

Effort must be made to define the content of K-12 engineering in a rigorous way. Katehi, et al.'s (2007) suggested that in order for engineering education to become a mainstream component of K-12 education, more high quality outcome based research will need to be completed. We need to figure out how science inquiry and mathematical reasoning can be combined with the engineering design process and placed into K-12 curricula, as well as become a part of teacher professional development. They suggested we contemplate the most important concepts, skills, and habits of mind in science and math that can be taught effectively using an engineering design approach. We should consider the circumstances in which students can use the engineering design process to learn important concepts and skills, as well as or better, than through regular science and math instruction. They encourage educators to think about using the engineering design process as a pedagogical tool, and to consider the professional development implications of using that strategy as a teaching tool in math and science. They also challenge educators to consider how to use STEM education as a natural connection among the four STEM subjects reflected in the real world of research and technology development. (pg. 8-9).

Cantrell, Pekcan, Itani, and Velasuez-Bryant (2006) reviewed how engineering concepts and activities could be aligned with science content standards in order to engage students to acquire rigorous science content knowledge. The program included professional development for teachers in order to improve their engineering content knowledge and to facilitate integrated technology to support effective science and mathematics instruction. This training included the development of lesson plans, web simulation, and three assessments. The authors noted that engineering design activities are a powerful way to integrate science, math, and technology. They found that these types of activities engaged students, although most popular science textbooks incorporated very few engineering activities or content.   They also noted that several researchers have shown that design challenges effectively engage middle school students in the engineering thought process. Students focus on function as well as structure, see design as an iterative process, incorporate team building activities, include cooperative learning and mentoring, and can use initial prototype designs and alternative methods, as well as using a Web based learning environment, to work through the process. Students made sense of their learning through reflection and discussion with other students, and connected the construction process to the underlying scientific and mathematical theory and equations.

Cantrell et al (2006) developed a Triangulated Learning Module in which the major question that generated the learning activity was focused on how to make a system work. The iterative process requires evidence, explanations, and connections to scientific and mathematical knowledge. The teacher began with introducing the students to science content necessary to begin the engineering project. Students then went to the Web to complete a simulation of the system or variable in the design project. After students collected and analyzed the data and interpreted the results, they used hands on materials to construct a prototype of their project, based on the data they collected. They shared their working system with their peers, showing a deep conceptual and applied understanding of the module topics. The learning modules contained four elements of the Kolb Learning Cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation often used in engineering. The 5 E Learning Cycle: engagement, exploration, explanation, extension, and evaluation was used in the progression of the activity. The task also contained three elements to facilitate student engagement with engineering content: simulation, construction, and connection. Unit tests, a rubric for design projects (worth 100 points: design, construction, data collection, and analysis), and interview protocols (worth 100 points: ten comprehensive concept questions to test content understanding / oral answers in a one on one setting with teacher and student) were used as the forms of assessment (pg. 303).

Garmire (2003) noted that according to the engineering design concepts taught by Dartmouth,

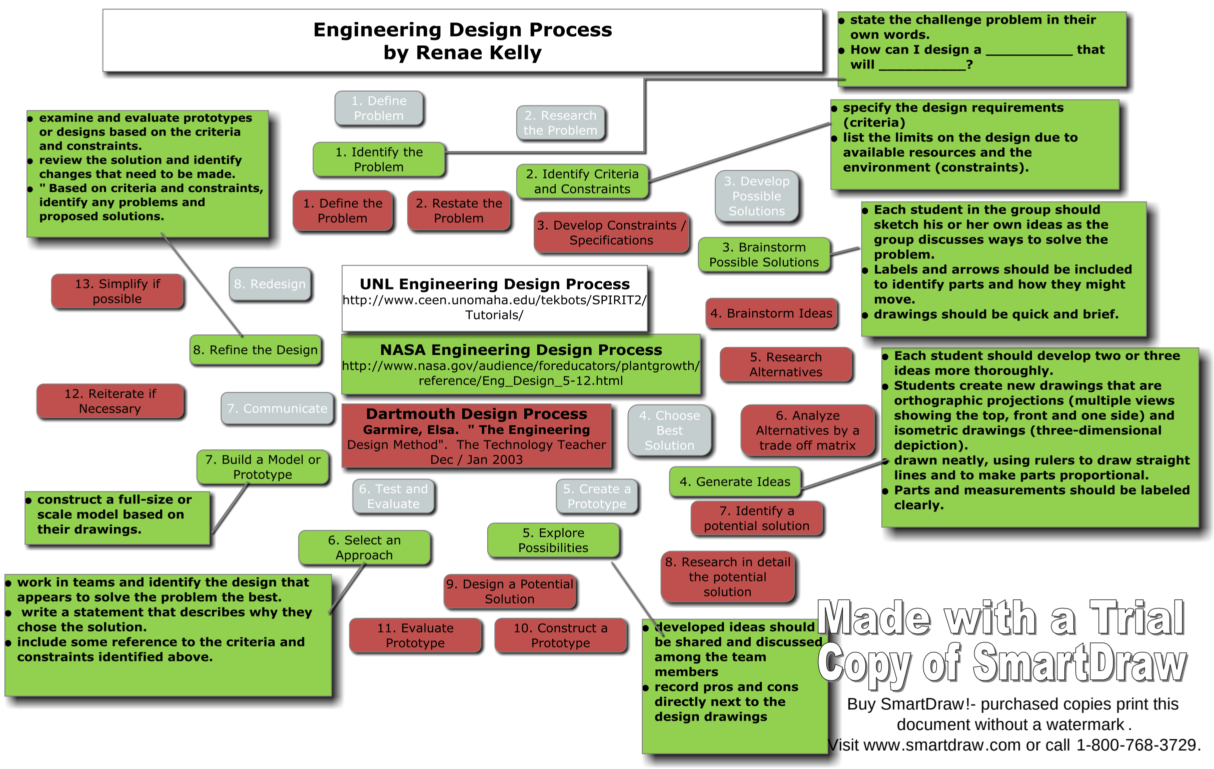
- All design is a compromise.
- Engineering design involves teamwork.
- Design process is not linear, but circularity as new information requires rethinking past decisions.
- The heart of the design process is the analysis of alternatives; resulting in a tradeoff matrix, evaluating possible solutions vs. criteria/specifications.

(pg. 22-26)

She recommended the design process be used as a framework for introducing students to design problems.   She felt that starting students on the right path to engaging in practices actually used in the industry showed that complex decision making can proceed in a methodical way.

There are several different engineering design process models. As part of my course work in NASA The "E" in STEM: Meaningful Content for Engineering I created a concept map analyzing some of the design processes I was exposed to (figure 2).

Figure 2



Sadler, P. M., Coyle, H. P., & Schwartz, M. (2000) viewed design projects as helping to show the connections between science concepts and solutions to real world problems. They noted that making the right connections should result in better solutions, since applying the wrong ideas in a design would make the solution work less well. If they would apply better ideas to the solution better results would be accomplished. They indicated that students should work for the best solution and not just a grade (pg. 303).

Design challenges allow students to test their preconceptions, identify which ideas work better than others, and allow multiple solutions to a problem. Each solution can then be evaluated by how well it satisfies the constraints laid out in the challenge presented.

Sadler, P. M. et al (2000), noted that design challenges provide opportunities to practice transferring new understandings to new situations, and provide a way to make sense of how things work. They further noted that a lack of exposure to design and use of manual skills might impede many students, as most of these skills are experienced outside of school. Providing these experiences within the school day can help to close the gap for those without such opportunities, making science accessible for all students (pg. 302). They stated in their research that, Roth (1998) noted several aspects of the design process that are relevant to teach science:

1. Design problems bring aspects of the real world to the science classroom.
2. Design brings a mental concept into a physical image, either as a sketch or as a prototype
3. Iterative design, demands change. Alternatives are generated and assessed. Reflection on a particular iteration and its performance is necessary to create the next iteration.
4. Design requires combining facts, concepts, and skills in order to reflect true understanding (pg. 304).

Sadler, P. M. et al (2000) suggested that by effectively scaffolding and supporting students at each developmental level, students will see substantial gains in conceptual understanding and in process skills. They found that by beginning with a step by step start up design, most students become immediately absorbed in the activity. Diagrams and step by step instructions allowed students with absolutely no background in construction, to succeed. The first prototype design was planned to be easy to build and instructive to improve. Middle school students appeared highly motivated to *best* what they perceived as their teacher's design. Students usually preferred to work on the initial challenge individually, to build self confidence, usually side by side with their friends (pg. 319).

Joannis N. Miaoulis (2009) from the Museum of Science in Boston noted that by 2015, she hopes to introduce engineering and technology to schools and at least one science center or informal education organization, in every state. This goal will help transform how children and adults understand technology and engineering, inspiring young people to pursue careers in engineering and technology. The key to getting our students to thrive in the global economy is to introduce students to engineering design skills and concepts that will allow them to apply their mathematical and scientific knowledge to solve real problems. She claims this is the way to harness the creativity of young minds and to fuel innovation of new technologies. School science still focuses on the natural, not the technological world, and teaches little to no engineering. She noted that the beauty of engineering is that the connector uses science and math to create technological innovations that will be used daily.

Miaoulis (2009) suggested many reasons to introduce engineering in K-12 schools:

1. **Engineering is rich in hands-on experiences.** Children are fascinated with building and taking things apart to see how they work.

- **Engineering brings math and science to life**, engaging children of differing abilities in problem-based learning, where teamwork is important.
- **To create a technologically literate work force**, we need to foster engineering as a career choice.

- **Technological literacy is basic literacy for the 21st century**. We need to understand how human-made things are created and how they work.

Mehalik, Doppelt, Schuun (2008) examined middle school students, and traditional scripted inquiry, or a design based systems approach. Their results showed that a design approach for teaching science concepts is better in terms of engaging students, facilitating core science knowledge concepts, achievements and retention of those concepts, then when compared to the scripted inquiry approach. They found the systems design approach was most helpful for low achieving African American students. Their systems design approach had students state their own needs for a particular design, and then had students develop requirements / design specifications that guided their design process. Students articulated their needs for the design, rather than having the design and its specifications proposed by the teacher or the curriculum. When students began with their own needs, it was possible to increase student motivation and engagement from the beginning, allowing students to see for themselves the relevance of the instructional task. It eliminated a barrier to learning: "Why do I have to know this?" (pg. 71-72).

The systems design approach permitted students to ask their own questions for investigation in order to design their solution. It allowed students to design their own experiments to investigate their ideas. The approach is organized according to modes of different types of thinking: needs, requirements, alternatives, and decision criteria, involving generative and analytical thinking; system parameters such as materials, energy and information inputs and outputs involving analytical thinking and synthesis thinking; contemplating alternative designs and selecting a design involving evaluative thinking; and inquiry into scientific materials, methods, and principles is another mode of thinking in a scaffolded series of modes of thinking. The findings showed that it was possible to achieve higher science concept learning when the scientific inquiry process was integrated into a design setting, motivated by meeting needs that students articulated themselves. (pg. 75-76)

Blumenfeld, Fishman, Krajcik, Marx (2000) noted that students' thinking skills, motivational dispositions, and knowledge are inadequate for them to lead fulfilling lives in a new global, information-rich, technology oriented world. They stated that the basis for all middle school science should be to have inquiry based science supported by pervasive technology tools. They examined how research influences practice and how practice can inform the creation of innovations that are sustainable in schools (pg. 149).

Students in traditional classrooms in my middle school fit this scenario. They do not seem willing to think through a situation, be motivated to quest for their own knowledge, and seem to just go through the motions in most of their classes. Blumenfeld, et al (2000) suggested that curriculum units be designed to last between 8 and 12 weeks. Students need opportunities to construct knowledge by solving real problems through asking and refining questions, designing and conducting investigations, gathering, analyzing, and interpreting information and data, drawing conclusions, and reporting findings (pg. 150).

Technology innovation is often hampered by lack of administrative knowledge about what equipment to acquire, what maintenance procedures to establish, what configurations of space and allocations of resources are beneficial, and what types of infrastructure to create. Whether instructional innovation is sustained depends on establishing appropriate polices and management. They may require new schedules, new resources, new assessments and new allocations of responsibility among different levels of the system.

I feel that my school really needs to look at how to arrange student schedules differently in order to meet students' learning needs. It seems to me following an eight period day with approximately forty to forty-five minutes of class each day, does not allow time for in-depth learning, or necessary differentiation of the curriculum to various levels of students. We also need to look at our curriculum guides in order to find ways to meet needs of students who already understand the content we plan to teach. I am currently working on finding ways to suggest various changes in my school district to improve opportunities for our students to achieve at a high level with support to build confidence and skills that will transfer to the work force. I am currently working on problem based learning projects that partner with community business partners, attempting to identify and solve real problems within the community surrounding my school.

Wenning (2005) pointed out that there is very little guidance or information about how to actually teach inquiry skills, even though it is one of the most central goals of science teaching. He suggested that a hierarchy must be provided for effective instruction to take place, so students have the tools they need to accomplish effective scientific inquiry. Teachers need to be able to teach the way they want their students to be involved in inquiry. They should explicitly model for students each of the levels of inquiry, modeling appropriate actions and then fading from the scene allowing students to implement the modeled inquiry processes. Each level should increase in intellectual sophistication and decrease in locus of control. He laid out the following levels of inquiry lessons:

- Discovery Learning:
- Interactive Demonstration:
- Inquiry Lesson

- Inquiry Lab
- Hypothetical Inquiry (pg.4-5).

Hammerman (2006) pointed out that the quality of lessons that guide the teaching and learning process remains a key factor in increasing student achievement. Instruction must focus on important goals and standards and research based effective practices in order to improve student achievement. "Teachers should work collaboratively in learning communities, planning lessons that target important concepts and skills, using data to inform their practice, and differentiate instruction to meet individual student needs." (pg. 18)

> "In this process teachers are enabled to align concepts and skills to important learning goals and assessments, broaden their understanding of important concepts and skills, apply a variety of methods, strategies, and resources to accommodate students' diversity and promote learning, research ways to link science to technology and society, and integrate science with other areas of the curriculum, design multiple and varied classroom assessments to provide feedback to students, and use data to guide instruction and, deliver instruction more confidently and effectively." (pg. 20)

The planning model provides a guideline for the design and delivery of inquiry based instruction. Components of high quality instruction are listed and strategies for applying the components to the design of lessons are listed to guide effective delivery. Teachers using this model embellish and modify lessons over time, improve strategies for effective delivery, and develop confidence in their ability to guide scientific inquiry. The planning model involves:

- **Clear Targets**
- **Important Concepts to Understand**
- **Meaningful Context**

- **Learning Cycle Activities and Experiences**
- **Integrated Reading and Writing / to Communicate Learning**
- **Connected to Students' Lives**
- **Assessment for Learning** (pg. 19)

Prestidge and Glaser (2000) focused their research on tools and resources teachers in 21st Century classrooms might use to find more authentic ways of assessing students' engagement and achievement in group research and multi-media projects. Students would have the additional benefit of valuing their published work and the importance of perfecting it for an authentic audience. The quality of the students' work and improvements made in the students' products highly correlated with the quality and frequency of the feedback provided. Many students felt empowered by the opportunity to voice their opinions about issues they had chosen to research. Reflective journals offered students space to write a paragraph, draw a picture, or construct some other artifact that would allow the teacher to "see" how the students were interpreting the information that was provided. Feedback was provided on the content and the level of reflection that was displayed in the work. Teachers made suggestions on the journal entries as to how the entries could be improved, or they provided prompts designed to help the students think more deeply about the information (pg. 179).

Barker and Ansorge (2007) note that robots help youth transform abstract science, engineering, and technology concepts, into concrete real-world understanding, through hands on experimentation. The use of robots, they note, is one way to teach the content of mathematics and science in such a way as to increase student understanding, and therefore improve their test scores on national and international tests in the areas of science and mathematics. Students can test the scientific and mechanical principles with the robots, so they can understand abstract concepts and gain a more functional level of understanding. Due to the interdisciplinary nature of robots, students learn to engineer robots and at the same time learn about many other disciplines as well. They begin to see how systems work together and depend on each other, and students begin to see the connections of systems education, since all the academic disciplines are trying to find ways to integrate their bodies of knowledge, rather than separate them (pg 230).

Barker et al (2007) noted that studies show robotics has high student interest and engagement, promotes learning of scientific and mathematic principles through experimentation, encourages problem solving, and promotes cooperative learning. Robotics also promotes interest in math and science careers. They suggest that we still need rigorous quantitative research designs based on achievement data about how robotics can increase STEM achievement in schools. More research is also needed to examine whether the program helps foster positive attitudes towards STEM in school and as a career. They further note that much of what an individual learns and understands is by integrating new knowledge with existing knowledge. Learning in this manner produces students who are responsible for their own learning, seek out new knowledge and are better prepared to generalize knowledge. Long-term content retention has also been shown to be a result of this type of experiential learning (pg. 230-231).

Williams, Ma, Prejean, and Ford (2007-08) note that there is very little empirical data to prove the impact of robotics activities on curricular goals. They suggest that evidence is needed to convince educators of the positive impact of robotics activities on curricular goals. Without evidence from research to support a direct impact on student achievement and academic performance, robotics activities may continue to be kept out of the regular classrooms and looked upon as nonessential to student achievement. Their study examines the effect of a two week robotics summer camp on middle school student's physics content knowledge and scientific inquiry skills. They claim that robotics activities provide a rich context needed for students to identify and investigate problems, generate hypotheses, gather and analyze data, and to determine findings and interpret results. Robots may provide an opportunity for learners to acquire STEM content knowledge since mathematics and physics are the foundation for engineering and programming, which are required in robotics development. Very little quantitative data measuring the direct impact of the activities on the students' learning has been gathered. Most of the research depends on observation and interview data. They noted that they did not find any studies that explicitly measured scientific inquiry skills as an outcome of a robotic intervention (pg. 203-204).

Williams, Ma, et al (2007-08) found in their study that students made significant progress quantitatively in their physics content knowledge, yet did not demonstrate significant improvement in their scientific inquiry skills performance assessment (pg. 210-212). Students did not seem to have a sense of what they wanted to achieve. At the end of their report they discussed the need for further research to define the explicit strategies needed to be used by teachers to facilitate scientific research skills in students, and how to foster the development of those skills.

Brand, Collver, Kasarda (2008) noted that the National Science Education Standards call for students to be actively engaged in solving problems that involve designing, constructing, analyzing, and proposing solutions to problems beyond the scope of the classroom. Robotics engages students in science through a nontraditional approach. Students explore robotics as a real world discipline, putting fundamentals learned to practical use. Instructors engage students by posing questions and encouraging discussions, analysis, and explanations of problems (pg. 45). In a design challenge a problem is posed to students, who must then use a set of materials to design machines that will complete a given task or solve an identified problem. After working on design problems, the class is then asked to critique groups' models for efficiency. Students define the constructive functions particular to each design challenge in terms of speed, robustness, and accuracy. Groups are encouraged to modify their robot with a renewed focus, attending only to the design elements that must be changed in order to achieve success in addressing the problem (pg. 47). The authors suggest that school districts be proactive and contact department heads and deans of local community colleges and universities to coordinate collaborative projects that will benefit current students and raise an interest level in pursuing advanced work at the given community college or university (pg 49).

LVJH took students to Southeast Community College last fall to participate in computer and robotics workshops. Prior to us bringing middle school students to their campus, the faculty had thought their intended audience should be high school students. After our visits, they could see the validity in catching student interest earlier, in the middle school grades, so students could more appropriately plan for their educational futures.

Lisa Clark (2002) shared that students who usually faced academic challenges displayed a remarkable talent in building and designing ROBOLAB k-12 curriculum module robots. The Lego Robotics System provided endless learning opportunities. As soon as students completed building and programming their own robots, they wanted to change how the robots looked and behaved. Like engineers in the real world, the students found that they were never really finished building and programming their robots—there was always something to change and improve. Students kept a reflective journal of their progress. They were assessed through written tests on the use of light and touch sensors in the real world, writing and creating programs to perform a specific task, and how the input and output devices may be used and modified. The factor that ultimately determined a robot's success was whether the robot performed a specific task and remained durable in its construction. Throughout the program, students increased their knowledge of robotics and engineering in the real world, strengthened cooperative group skills, improved visual spatial skills, developed an understanding of how to write a simple computer program, and enhanced their presentation skills (pg. 41-42).

Owen Edwards (2008) noted increased interest in robotics in school science curricula, can be credited to the inventor Dean Kamen, who launched the FIRST (For Inspiration and Recognition of Science and Technology) Robotics Competition in 1989. Today, more than 32,000 students on 1,500 high school teams from all over the world have competed, and the program has brought robotics to students from ages 6 to 16. Emporia State University in Kansas now requires two instructional-technology courses, to help education students incorporate robotics as a useful tool for modeling teaching strategies. The courses emphasize social science as well as engineering. This allows students to view robots as more than just a science lesson, and provides collaborative learning experiences that use higher-order thinking and learning styles.

Barker and Ansorge (2006) suggested ways to run robotics competitions. First purchase Lego Mindstorms For Schools Robotics Kits. Then organize a hands-on robotics training workshop for interested participants. Skills to cover in the workshop should be:

- Basic robot building
- Basic robot programming

- Basic sensor programming and building
- Line tracking

Participants should then be ready to begin forming their own robotics teams, establishing rules, and determining how scoring will take place, at a competition held later in the year. The next job is to build the arena for competition and practice, and then run the competition. Barker et al (2006) suggested more research is needed to determine the effectiveness of using robotics to teach STEM concepts.

Nugent , Barker, Grandgenett, and Adamchuk (2009) noted that educational robots and GPS receivers involve much digital manipulation and allow for hands on, minds on, self directed learning. They further suggest that the research supports the use of educational robotics to increase academic achievement in specific STEM concept areas closely aligned with formal education topics and coursework. This group's research documented the impact of the robotics and GPS/GIS program as it improved STEM learning and attitudes after a series of robotic experiences, compared with the limited experiences of the control group.   They noted that their results to date suggest the benefits to student involvement may be increased STEM conceptual knowledge, increased interest in STEM subject areas, and greater self-efficacy in problem solving approaches and technology based tasks. Educational robotics and GPS/GIS technologies seem to provide a natural context for youth engagement and dynamic interaction. The use of these technologies appears to be a promising strategy to help support overall STEM learning goals and to increase general student interest in STEM.

Grandgenett, N., Chen, B., Ostler, E., & Timms, M. (Eds.). (2009) pointed out that curriculum is being developed, targeting the instruction of specific robotics related topics or "touch points" in science, technology, engineering, and mathematics (STEM). Their work is built upon the previous work of a NSF ITEST project called SPIRIT (Silicon Prairie Initiative for Robotics in Information Technology), where teachers were trained in robotics and engineering concepts. The project is investigating whether students undertaking educational robotics lessons will demonstrate an increased learning of specific STEM topics, an enhanced attitude toward STEM, and whether they will become more motivated to undertake advanced STEM coursework. The curriculum "touch points" where teachers can use robotics to illustrate middle school STEM concepts, are being written to tie to specific concepts taught in the math and science curriculum. Along side of the full curriculum lessons, thirteen games to explore CEENBoT™ movements have also been created, edited and posted. Lessons are currently available to teachers piloting the lessons: Science – 49 completed lessons, Technology – 8 completed lessons, Engineering – 10 lessons, and Mathematics – 43 completed lessons. The writing of mathematics lessons has been particularly emphasized, with a special focus on introductory algebra. All lessons can be viewed under their primary headings at the SPIRIT lesson website of: http://www.ceen.unomaha.edu/TekBots/SPIRIT2/ . Over the last year, I helped write and / or edit several of the lessons presented on this particular website. I am currently using the lessons to motivate and increase student understanding of various beginning algebraic concepts.

Students taking part in the lessons from this website are evaluated with assessments to document their attitudes and achievement. The assessments are well developed instruments and are known nationally, previously used and validated within a variety of educational settings, summer camps, and after school programs, by (Barker, Nugent, Grandgenett, Hampton, 2008) including work within the MOEC area schools. The content assessment is a 39 question, short multiple choice quiz, related to mathematics and science that can be found in a robotics context.

A 33 question attitude instrument uses a Likert-scale asking students about mathematics, science, and learning.

Grandgenett et al (2009) noted that three hours of robotics activities, probably does not provide enough time to cover topics with sufficient depth and structure to promote real student understanding that can be demonstrated on the content assessments, due to the short duration of events, and lack of time to fully explore the concepts and processes necessary to impact learning. They did find that students' attitudes towards science, mathematics, robotics, and geospatial technologies all increased from pre to post, as well as their self-efficacy with robotics. This result is likely due to the fact that the activities in the three hour pilot testing interventions were specifically selected and designed to be highly engaging and motivating, with limited cognitive load.

It appears much more research needs to take place in order to verify the positive educational outcomes of robotics and the engineering design process, as it relates to the acquisition of STEM related concept attainment, as well as motivation and student interest in the areas of science, technology, engineering, and math, in students.

Research Questions

Questions I am seeking answers to:

- Do robotics and the engineering design process play a positive influence on student achievement and motivation in STEM related concepts at the middle school level?
- How well can students document their thinking, in order to share the process they went through to solve a given design challenge?
- When a student uses a "hands on, minds on, inquiry-based" activity format, will the

student will be able to understand several academic concepts being taught at a deeper level, when learned in context to the real world?

- Does the engineering and design process create engaged students, intrinsically motivated to learn by the desire to understand how and why something works, rather than be assigned something to learn?
- How can I be the catalyst in my school district for changing the way we think and teach science topics to youngsters?

Methods

Setting

Location.

The City of La Vista, NE is a progressive city situated southwest of the Omaha metropolitan area. It is one of the newest and fastest growing cities in the state of Nebraska, located just minutes from Offutt Air Force Base, Eppley Airfield, and the Interstate Highway system. La Vista has grown to a community of approximately 17,000 people since its incorporation in 1960. It has several leading businesses within its boundaries, due to its location and because of the commitment of the Mayor and City Council. The community welcomes a progressive plan for future growth, and is able to attract and retain various businesses and highly skilled residents. Some businesses calling La Vista home are: Yahoo Data Center, Cabela’s Inc., Hampton Inn and Suites, John Q. Hammons Embassy Suites Hotel/Convention Center, PayPal (an EBay company), HP Computers, Streck Laboratories, Inc., CSG Systems, Inc, Rotella’s Bakery, Education Service Unit # 3, Oriental Trading Co., and Claas Omaha, as well as many other businesses.

Participants

According to the *Membership Report from NSSRS*, NE Dept. of Educ. (2009-2010), nearly one fourth of the student population of La Vista Junior High is from lower socioeconomic homes, receiving either free or reduced lunches. Reviewing the chart of information gathered from that report, in Appendix 1, you can see that most of the student population is white, with very few minorities represented in the fifteen percent of students that are non-white. The minority population is mainly Hispanic, followed closely by black, not Hispanic. Very few minorities are of Asian, Pacific Islander, or Native American descent attending La Vista Junior High. Male and female students are represented in about the same numbers in both the seventh and eighth grades.

Classroom context.

Set 1.

All of the eighth grade students from their assigned section of science were participants in the first section of my research. The 302 eighth grade students were divided into three separate academic teams, with each team sharing the same core academic subject teachers. Students from each team were divided into five separate sections for each subject area. I presented the *Design Squad: On the Moon: Touchdown Challenge* to each section, of each team, during one 45 minute science class, within a two week period. The design challenge was presented near the end of the astronomy unit, involving the study of the sun, moon, and the earth. Periods 2, 3, 5, 7 and 8 were filled with approximately 20 students in each science class, on three different teams with three different teachers. Students reported to their science classroom each day, with lab tables and chairs set up facing the front of the classroom, with two students sitting at each lab table.

Set 2.

The second set of study participants were seventh grade students, enrolled in the fifth session of a six week elective course, involving technology education at La Vista Junior High. “Tech Ed 1” is the first course offered to students in technology education at La Vista Junior High. It is a required six week exploratory course, for all students in seventh grade. Within the six week period, students are required to do several projects. Studying robotics with the use of Lego Mindstorms NXT, and lessons from the Carnegie Mellon: Robotics Engineering software, students spend 8 to 10 class periods working through the first lessons: “Full Speed Ahead”, and “Wheels and Distance”.

Students were separated into three sections, according to their daily scheduled course assignments. Just prior to spring break, forty-eight seventh grade students responded to the online questionnaires/assessment prior to the series of robotics lessons. Fifty one students responded to the post test online questionnaires/assessments at the end of the robotics unit.

- 8.3% were African American
- 2.1% were American Indian
- 4.2% were Asian or Pacific Islander
- 12.5% were Hispanic
- 62.5% were white
- 10.4 % listed their ethnicity as other than the breakdown above
- 45.8% were male
- 54.2% were female
- 18.8% were only 12 years old
- 79.2% were 13 years old

Students were presented the first of two projects, from *Robotics Engineering Volume 1* with directions that could also be accessed through an electronic format, so they could work at their own pace, reviewing instructional media (written directions, verbal directions, along with video clips), to help them develop a deeper understanding of the steps needed to be taken. Students worked through the assignments at their own pace, together with their "lab partner", answering questions posed along the way.

Data Collection

Sources.

Set 1. Student Engineering Notebook Pages from <u>Design Squad: "On the Moon Challenge: TouchDown</u>". *(Appendix 3B)*

Students reported their progress and thoughts throughout the design process on a page of graph paper provided to them at the beginning of the challenge. I was interested in gathering information about how well students were able to document their thinking, in order to share their process of solving the challenge with other students in the class.

I began in December to work through the *Design Squad "On the Moon Challenge: Touchdown"*, recording my own thoughts and findings, in the same manner I would be expecting students to work through. On Jan. 5th, 28th, and Feb. 1st, I worked with three different eighth grade teams of students during their regularly scheduled science class, in a single 45 minute class period session. Students were instructed to write down everything they brainstormed, as well as tried, and then to record how their tests worked out and what they planned to do to improve their design, sharing their findings with the class and recording the final results. Students worked as collaborative partners thinking first on their own, and then putting their heads together to come up with a final solution.

Set 2.

I was interested in gathering information from the students concerning the study of robotics and its connection to student motivation and achievement in mathematics and science. I emailed the authors of the SPIRIT and 4-H Robotics (Barker, Nugent, Grandgenett, Hampton, 2008) and (Grandgenett, 2009) research reports (see Appendix 4A), in order to seek permission to use those data collection pieces in my research. I transposed their questions into an online survey format, in order to facilitate ease of collecting and analyzing the data. A paper format of the online surveys can be found in Appendix 4B-4D. I chose to use the same assessments concerning robotics as those used by (Barker, Nugent, Grandgenett, Hampton, 2008) and (Grandgenett, 2009), so that comparison of findings could take place if so desired. Validity had already been established for the two instruments. The content assessment test (see Appendix 4B) contained 24 short multiple-choice questions related to mathematics and science concepts found in a robotics context. The Interest Questionnaire (see Appendix 4C) used a Likert-scale, asking students 44 questions concerning attitudes about mathematics, science, and learning. Both assessments are well known nationally, have been validated within a variety of educational settings, summer camps, and after-school programs, including previous work within the MOEC area schools (Barker, Nugent, Grandgenett, Hampton, 2008; Grandgenett, 2009). I am very familiar with these tests and have helped gather data, using these exact instruments, several times throughout the last year.

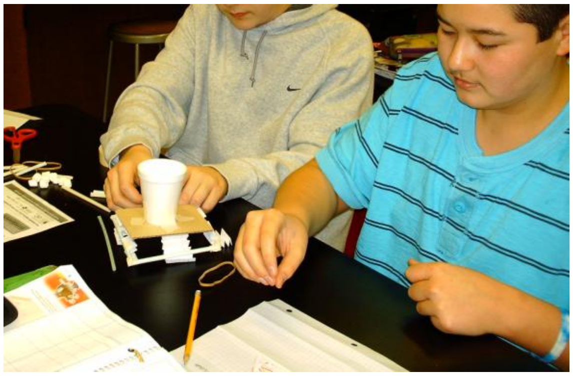
Data collection processes.

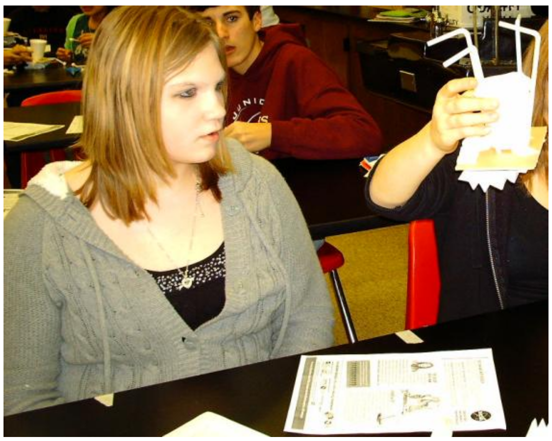
Set 1.

Each class period I instructed students to set up their notebook page, following the format found in Appendix 3A. I collected students' notebook pages at the end of the period, as well as their prototype “lunar lander”, to display in the media center during parent teacher conferences. I took pictures of the prototype models, and made copies of the student notebook sheets, so they could take the originals home.

The first teacher to have me into his classroom to present the challenge to his eighth graders said, “This activity really helped students think through space shuttle design, using a hands-on approach. When students are faced with a competition, they become so much more motivated and try to out-think their opponents.” Due to his enthusiasm for the project, the two other science teachers wanted me to present the challenge to their classes, as well.

Student pairs created and tested out their solutions.





(Photo release in appendix 3C)

Set 2.

Prior to spring break, I had students in all three tech. ed. classes complete an online content pretest, involving the programming of LEGO Mindstorm NXT robots, and two attitudinal surveys. The three online assessments were created from the questions used in the previous two studies mentioned earlier. Paper forms of the online questions can be found in Appendix 4B-4D. Immediately after spring break, I caught up any missing students that did not complete the pretest instruments. I contemplated using lessons from the 4-H Robotics curriculum to help guide students in the engineering design process, solving various problems and living within the limits of materials and constraints given to them in the curriculum. The lessons did not seem to be as easy to follow as the ones already used in the Tech 1 course from the Carnegie Mellon *Robotics Engineering Volume 1*.

I spent the rest of the week interacting with students and posing questions to them, to probe their thinking, as they worked through the robotics challenges from *Volume 1 of Robotics Engineering*. Students were to work through the lesson "Full Speed Ahead" and answer the questions throughout the lesson in their notebooks. A follow-up worksheet was provided as a self graded quiz, to test the mastery of their understanding of how to move a robot forward. Next students worked through the lesson entitled "Wheels and Distance". We worked together to understand how to use circumference, in order to determine the distance a robot would travel, as compared to how many wheel rotations were programmed to move the robot forward. When the full class mini-lesson was completed, students were to try to program their robot to move a certain distance and then stop. Several students were not able to complete that part of the lesson, due to running out of time to complete all sections of the previous programmed lesson they were following.

Students provided online feedback to me, in the form of a survey, after the end of the unit (two lesson modules: “Full Speed Ahead”, and “Wheels and Distance”), and also took posttest assessments and questionnaires, with the same content as the pretests. I reviewed the data, looking for changes in motivation in the questionnaires’ answers, or changes in achievement through correct answers on the content test.

Since I only had a short implementation time for my study, I chose to use the feedback forms for students only (see Appendix 4D). They evaluated how the activity went, and how it could be improved. Grandgenett (2009) used these same forms to receive feedback from both instructors and students in his study. I did not use the instructor feedback forms, since I ended up using the same curriculum that the tech teachers currently use to present robotics’ challenges to students in their classes.

Data Analysis

As a result data analysis, I reviewed the findings in order substantiate answers to any of my questions:

1. In what ways do robotics and the engineering design process influence student achievement and motivation in STEM related concepts at the middle school level?
2. How well can students document their thinking, in order to share the process they went through to solve a given design challenge?
3. How will connecting academic concepts together with real world activities, affect the level of student understanding?
4. In what ways does engineering and design process affect student engagement and motivation?
5. How can I be the catalyst in my school district for changing the way we think and teach

science topics to youngsters?

Methods Used to Analyze the Data.

Set 1.

Students' prototypes were displayed in the media center at parent teacher conferences. I photographed the displays and made copies of all student engineering notebook entries, in order to analyze them further. I sorted through the student writings and placed them into piles according to the following criteria (Appendix 3C contains examples of each type of entry submitted by various students):

- Complete and Thorough Documentation
- Redesign - Too General for Ideas to Move Forward
- No Redesign after first testing prototype
- Incomplete report, important documentation missing

I reviewed the results of the number of students in each core group whose written reports fell into the above categories. I then created a chart to document the findings. These results can be found in Appendix 3D.

Set 2.

Pre and post content test analysis. (Appendix 5A-5B)

Reviewing the data collected from the students through the online assessments. First, I collected the responses to the pre and post content assessment and compared the results of each, using a spreadsheet. I created a table showing the correct number of responses on the pre assessment along with those of the post assessment, and noted the changes in correct number of responses. That data can be found in the following table:

Question	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Final Score
Pre Content	28	18	25	37	13	36	9	41	11	13	29	27	23	11	15	16	18	21	9	400
Post Content	31	18	18	26	13	27	10	26	17	16	24	19	19	15	18	18	17	19	8	359
Amount of Change	3	0	-7	-11	0	-9	1	-15	6	3	-5	-8	-4	4	3	2	-1	-2	-1	-41

I reviewed the data from both assessments and found all three forms of central tendencies and noted them in Appendix 5A. Four students answered at least 70% of the questions correctly on the post test, while only three students answered with a passing score on the pre test. Overall students scored more between 1 and 2 correct answers less on the post test, than on the pretest.

	Pre	Post
Mean	7.407	6.648
Median	7	5
Mode	7	5

I further analyzed the content questions, by reviewing the answers given by the students in the post assessment. That analysis is found in Appendix 5B. Changes that had a lower number of correct responses in the post assessment data, I highlighted in red. I noted the change in correct response as an integer, noting the difference from the pre-assessment content score and the post assessment content score.

Pre and post survey question analysis. (Appendix 6)

I reviewed answers to the interest survey in terms of individual questions and compared the responses from the pre-assessment interest survey to the post assessment interest survey. I noted the questions that had the most meaningful change between the pre and the post data collection. Several of those questions are displayed for the reader to compare, in Appendix 6.

Student feedback after robotics sessions. (Appendix 7-8)

Appendix 7 displays some post assessment data concerning students' attitudes and interests in STEM activities and careers. I reviewed comments students made in the student survey administered at the end of the robotics unit, and pasted them into a word document. Then I manipulated the comments students made, in order to group them together categorically. I highlighted comments that seemed related, in the same color, and moved them adjacent to each other in order to group like comments together. I then reviewed the various groups of like comments, looking for ways to categorize them. Then I analyzed the various groups of like comments, to link them to common themes that relate to student motivation and achievement. The results for this analysis can be found in appendix 8.

Findings

When I presented the design challenge to each eighth grade science class at the beginning of second semester, students were very engaged throughout the entire activity, to create a "lunar lander" that would touch down gently. The "Touchdown" challenge completed by over 300 eighth grade students, working in partners, had very few design solutions that were exactly alike. We had similar solution ideas, but each prototype was unique in some way. The classroom science teachers were amazed at how engaged the entire class was for the whole period. They were surprised at how involved all students were, even those that normally have difficulty attending to the lesson during regular science class.

Students need to have constructive feedback and high expectations to document their scientific thinking and progression of activities. Some were able to do that, but most were still trying to get to the correct answer, and were not used to thinking creatively during many of their core classes.

Students in the robotics classes often had difficulty following the multimedia lessons, and preferred to wait to have someone show them specifically what to do, rather than think through the problem themselves, and come up with a solution. Some students were begging to be able to work through a challenge on their own, while others were perfectly content to be directed each step of the way, and were not comfortable or willing to take on the initiative to work things out, when they did not find their first few attempts to be successful.

Most did not have enough solid practice in the robot module lessons to have mastered the content at a proficient level. It is helpful to note, that the post test had to be administered after the end of the six week rotation for the tech ed. elective class. Students did not have any real sense of needing to think thoroughly through the questions, as the class was over, and many were ready to move on with the next rotation of elective courses.

Description of Findings

Set 1. Engineering Notebook Analysis Results

Categories	H	T	S	Percentage	Total
Complete and Thorough Documentation:	24	9	10	15.7%	43 total
Redesign – Too General for Ideas to Move Forward:	11	54	47	40.9%	112 total
No Redesign after first testing prototype:	26	19	37	29.9%	82 total
Incomplete report, important documentation missing:	31	5	1	13.5%	37 total

Set 2.

Pre and post content test analysis. (Appendix 5A-5B)

I reviewed the amount of change that took place on each question. The following questions had the most change from pre to post in number of incorrect answers:

1. *Which of the following is a wireless connection?*
2. *Which of the following enables a robot to investigate and react to its environment?*
3. *Which of the following strategies would be important to evaluating Amie and Cody's solution?*

4. *Amie and Cody are reviewing the possible solutions to select one to test by building a prototype. Which of the solutions below do you think is most important to the project?*

These questions fully support the need for students to know about and understand the technology they live with and around. Students need to be able to take full advantage of the devices they have available and know how to program to do the work they need to do. The results of this content quiz show the deficit our students have in understanding the technology around them, especially that which they were in contact with for two weeks prior to the post test. This also suggests that students need more guided work with these types of devices, in order to develop a full understanding of them.

The following question had the most change from pre to post in number of correct answers:

> *The process of refining an instrument, like your robot, so that it is as accurate as possible by collecting information about how far your robot will travel in a given amount of time and using the information to estimate how long it will take the robot to go a given distance is called _____.*

I believe that this question was very well covered in the "Wheels and Distance" lesson and since it was one of the main concepts in the lesson, it provided students the opportunity to answer it correctly after working with the robot challenges during the previous school days.

Pre and post survey question analysis. (Appendix 6)

I reviewed answers to the interest survey in terms of individual questions and compared the responses from the pre-assessment interest survey to the post assessment interest survey.

- Most students answered the question about confidence in programming a robot that behaves unexpectedly, as having very little confidence pre or post that they could resolve the issue.
- Thirteen percent of the students were not as likely to analyze a problem before they began a solution in the post survey as compared to the pre survey questionnaire.
- Only about 42% of students said that they would break down a complex task into smaller steps in the post survey, as compared to about 59% on the pre survey.
- After working with the robots several students were less sure they like working with new technologies such as robots.
- After the lessons, almost 63% of the students felt confident that they could program a robot to move forward two wheel rotations, and then stop, which was a specific objective worked on in the second lesson.

Student feedback after robotics sessions. (Appendix 7-8)

Reviewing the results of student feedback I found:

- 60 percent of students agree mathematical formulas are helpful in solving problems.
- 62% think it is important to use accurate measurements to help solve mathematical problems.
- 45 % of students liked learning about robots, while 35% were neutral about it.
- 62.5 % were confident they could program the robot similar to the challenge in lesson one.
- Only 39.6% of the students try new methods to solve a problem when one does not work.
- Only 39.6 % break down a problem into smaller steps to solve a complex problem.

- Only 33% felt they could fix a software problem when the robot did not behave as expected.

Emergent themes.

As I manipulated comments students made, reviewed the contents of those comments, and tried to link them to common themes, I came up with the following categories of comments:

- Student Engagement--- fun, learning to program and see the results, self discovery
- Lack of Problem Solving Skills—Too difficult, boring, need more guidance,
- Building of Skills to develop confidence -- Need more time, self discovery

Student engagement.

Hands on = minds on / engaged learners.

All students were engaged throughout the *On the Moon Challenge: Touchdown* process, and were motivated to come up with a workable solution to share with the class by the end of the period. All three classroom science teachers commented about how all students were on task for the entire period, even those who typically have difficulty attending to regular science lessons and labs with much involvement or excitement.

Lack of adequate problem solving skills.

1. Comments from Student Survey after Robotics Lessons (see Appendix 8)

   "For you personally, how could the lesson or activity be improved?"

   - "I would have liked a little more guidance in the project."
   - "By getting a better understanding"
   - "I think that it could be improved by making it easier and less math."
   - "More directions."

- “I think the lesson could be improved by making less math in it.”
- “Trying to make the programming a little bit easier then how it is, because it is very confusing.”
- “Doing more videos to explain better.”
- “Like sometimes the things that they made us do were confusing, so I didn't understand them.”
- “It could be better explained on *Wheels and Distance* because the videos were very confusing, and I had no idea what I was doing.”
- “Having a little easier direction on how to make the program.”
- “I think it could be improved by making the "blank canvas" easier to understand.”
- “Help people so they can enjoy it like everyone else.”

2. Students Need to be Allowed to use Their Creativity to Create a Solution to a Given Challenge or Problem:

   Comments from Student Survey after Robotics Lessons (see Appendix 8)

   “For you personally, how could the lesson or activity be improved?”

   - “well they could make it a lot more interesting for everyone and let the kids choose the partners they wanted and let the kids to more movements instead of just straight lines and twisting”
   - “Maybe have us do different experiments and we teach the class what other things can be done by the robot.”

- “you could let us build the robots”
- “by us making the robot on our own”
- “if we got to actually make the robot instead of just programming the robot.”

3. Student responses comparing the answer to the prompt: “In order to solve a complex problem, I break it down into smaller steps.” (See Appendix 7)

    Pre (strongly agree and agree = almost 70%)

    Post (strongly agree and agree = only 41%)

    Almost 70 percent of the students agreed on the pre assessment survey, while only 41 percent agreed with the statement on the post assessment survey.

4. As students worked through the robotics lessons, many had to ask for help from the instructor in order to try to figure out what to do next, to get their robot to work correctly, even though material to refer to was available for them to access.

5. In response to the statement. “I try new methods to solve a problem when one does not work,”

    Pre (strongly agree and agree = 67%)

    Post (strongly agree and agree = only 39%)

    Sixty-seven percent of the students agreed on the pre assessment survey while only 39 percent agreed with the statement on the post assessment survey. (See Appendix 7)

6. Difficulty in Tasks Often Results in Perceptions of Boredom: Comments from Student Survey after Robotics Lessons (see Appendix 8)

“For you personally, how could the lesson or activity be improved?”

- “I would have liked a little more guidance in the project.”
- “By getting a better understanding.”
- “I think that it could be improved by making it easier, and less math.”
- “More directions.”
- “I think the lesson could be improved by making less math in it.”
- “Trying to make the programming a little bit easier then how it is, because it is very confusing.”
- “Doing more videos to explain better.”
- “Like sometimes the things that they made us do were confusing, so I didn't understand them.”
- “It could be better explained on *Wheels and Distance* because the videos were very confusing, and I had no idea what I was doing.”
- “Having a little easier direction on how to make the program.”
- “I think it could be improved by making the "blank canvas" easier to understand.”
- “Help people so they can enjoy it like everyone else.”
- “It was boring.
- “I thought it was boring.”
- “It was fun and kind of boring.”
- “It should be more fun, it was very boring and dull and I was very disappointed”

- "I think we need to have some more fun and not watch all the videos. They got very boring."

Building student skills.

1. Lack of Knowledge or Discipline to Fully Document Thought Processes While Working Through a Given Challenge:

Reviewing student notebook pages, I categorized their work into various piles. (See Appendix 3B and 3D)

Categories	H	T	S	Percentage	Total
Complete and Thorough Documentation	24	9	10	15.7%	43 total
Redesign - Too General	11	54	47	40.9%	112 total
No Redesign After First Testing Prototype	26	19	37	29.9%	82 total
Incomplete Report, Important Documentation Missing:	31	5	1	13.5%	37 total

2. Students wanted More Exploration of a Topic or Project in Depth:

   Comments from Student Survey after Robotics Lessons (see Appendix 8)

   "For you personally, how could the lesson or activity be improved?"

   - "If we did it longer."
   - "More activities."
   - "Getting more time to work on the project."
   - "By maybe working more on the project."
   - "Slow it down."
   - "Add another day so we could do the robot challenge."
   - "I think that the lesson should have been longer."
   - "I think the lesson could be improved by allowing more time to program different things on the robot instead of just moving around. I mean like talking or jumping."

3. Opportunities for Repeated Real World Practice Develop Transferable Skills:

   2. Over sixty percent of the students were confident they could program a robot to move forward two rotations after working through the lessons which guided them in how to complete that challenge. Only 45 percent of students thought they could program the robot to move forward two rotations prior to the robotics unit. (See Appendix 7)

      Pre (strongly agree and agree = 45%)

      Post (strongly agree and agree = 60.5%)

   3. Longevity of Interest / Attitude Lacking after a Project/Course is Completed:

      Pre (strongly agree and agree = 57%)

Post (strongly agree and agree = only 45%)

Fifty-seven percent of students survey agreed that they, "like learning new technologies such as robotics" before the unit began. Only forty-five percent of the students agreed after the robotics unit ended.

4. Practicing Skills Similar to those Assessed, Develops Confidence and Ability: On the post content assessment, six more students answered the calibration question with a correct response than answered correctly on the pre content assessment. (See Appendix 5B)

5. Students presented many comments about how much they enjoyed programming the robots to perform certain movements. (See Appendix 8)

Personally the best part of the lesson was:

- "Making the robots turn."
- "I liked programming the robot."
- "Making the robot move, because it helped see far it went."
- "I think that the best part of the lesson was seeing the robots actually do what you showed them to do."
- "The best part of the lesson was when we got to see the robot do the actions that we programmed."
- "I think the best part of this lesson is seeing how the robot worked when the programming is set."
- "Downloading the programs and seeing if they would work."
- "Making the robot move, because it helped you see how much you did."
- "Seeing your robot do what you told it to do."

- "The best part was that we actually made the robot move, which was very fun."
- "The best part was seeing the robot move, because I know that I was the one who did it."
- "The best part was watching the robots do what you told them to do."
- "Being able to program a robot to do what I want it to."
- "I liked making the robot do different things, because I like to experiment and try different things."
- "The best part to me was when we got to test the programs, because we got to see if our programs worked."
- "I think the fun part was when we programmed the robot."
- "Programming the robot to go forward."
- "Having the robot to go a certain distance and the come back."
- "Calculating the rotations of distance, because it was the easier thing to do."
- "Making the robot move."
- "Getting to make the robot move a certain distance and back."
- "The best part was that we were able to see what we had done."
- "*Full Speed Ahead* because you made it go fast."

6. Over sixty percent of the students were confident they could program a robot to move forward two rotations after working through the lessons which guided them in how to complete that challenge. Only 45 percent of students thought they could program the robot to move forward two rotations prior to the robotics unit. (See Appendix 7)

Discussion of Findings

As I reviewed the data, I noticed that students still had a long way to go in order to become the persistent problem solvers we want them to become. Many felt helpless, and wanted to be told or shown how to make the robot or program work, or solve whatever problem they were facing.   They didn’t want to review the videos or read the information, in order to figure out how to find out why the program did not work as it needed to.

Several students responded that they did not continue to try to solve a problem if it was too difficult. Many did not have a sense of how to break down a complex task into smaller steps to make it more manageable. This data showed me, that our task, as educators and parents is really to place more and more problems in front of our students and let them figure out how to solve them. We need to encourage them to “muck around” with a situation, until they can figure it out. We should ask probing questions to help students find a workable solution, and we must allow them to work through “the mess”, so they will be able to be successful when trouble shooting in the real world.

The small sampling of only 48 students in the Set 2 group, convinced me feel that our building goal of problem solving was one that continues to need improvement on. We definitely are not where we want kids to be as problem solvers in many different situations and ways of thinking. I believe the questions the School Improvement Team developed last year were ones we need to continue to develop workable solutions and answers to, in the next school year.

Thoughts on My Original Research Questions

1. **Do robotics and the engineering design process play a positive influence on student achievement and motivation in STEM related concepts at the middle school level?**

According to the data collected in both the On the Moon Challenge and the Robotics Challenges, I believe that students are begging for a new way to learn things rather than the traditional lecture and notes method, regurgitating information back to the instructor when the unit is completed. Students desire a more exploratory approach, where they can think through a problem, and come up with the best possible solution they can. It was made apparent in the robotics challenge that students need much encouragement and guidance to work through the challenges, without having the solutions given to them.

2. **How well can students document their thinking, in order to share the process they went through to solve a given design challenge?** Most students showed that they need more guidance and practice in this area. Only 15 percent of the entire eighth grade population had a paper that fell in the complete and thorough category. Much of the literature reviewed suggested that students need to be explicitly taught how to carefully document their thinking processes, and then be specifically coached, as they work through learning how to record their actions and thoughts adequately on their own. Needing to revisit a problem and redesign a better solution will facilitate the need for better note taking, in order to move on from where they left off previously, or from another researchers' work.

3. **When a student uses a "hands on, minds on, inquiry-based" activity format, will the student will be able to understand several academic concepts being taught at a deeper level, when learned in context to the real world?** Students had difficulty learning the concepts needed to be mastered when left to work through a problem on their own. They desire guidance, maybe even the reason for a particular rule. I suggest

that when students are at the point of wondering how they might begin to figure out why their solutions are not working, would be the time when class discussion, facilitated by the instructor, could lead students to the necessary concept exploration. This in turn could get students to try out their individual ideas and see how mathematical and scientific principles might help them better understand a workable solution to their particular challenge. This is very much tied to the idea of authentic learning, with real world connections. The Socratic method of questioning may be just what students need to get their minds going, rather than to sit through someone else instructing them on what and how to think.

4. Does the engineering and design process create engaged students, intrinsically motivated to learn by the desire to understand how and why something works, rather than be assigned something to learn?

Students are begging for the kind of work that is meaningful to them. Presenting them with challenges that they need to solve, with certain criteria and constraints to follow, but no predetermined answers, is really what gets students excited about what they are doing. They want to be active engaged learners and not just someone who sits and listens.

5. How can I be the catalyst in my school district for changing the way we think and teach science topics to youngsters? I can start by sharing my findings with the School Improvement Team in my building, and then helping teachers find resources that will allow them to teach students in a new and different way, using the engineering and design process as they present students with challenges to resolve rather than assignments to complete.

Themes Evident in the Data are Made Meaningful in Light of the Literature Review

Student engagement.

Hands on = minds on / engaged learners.

Robin Shoop (2005) noted that the desire for competence and understanding stimulates the learning process. Prensky (2006) suggested that we regard student engagement as more important than content, when teaching and to pay attention to how our students learn, finding out what they already know, and value and honor that knowledge.

Katehi, Pearson, Feder (2007) noted that K-12 engineering education should emphasize the design process, be incorporated into important and developmentally appropriate mathematics, science, and technology skills, and promote engineering habits of mind: systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations.

Cantrell, Pekcan, Itani, and Velasuez-Bryant (2006) noted that engineering design activities are a powerful way to integrate science, math , and technology. They too found that these types of activities engaged students, helped them focus on function as well as structure, see the design as an iterative process, incorporate team building activities, include cooperative learning and mentoring. They found that students made sense of their learning through reflection and discussion with other students and connected the construction process to the underlying scientific and mathematical theory and equations.

Lack of adequate problem solving skills.

Many Possible Alternative Solutions to a Given Problem.

The ISTE framework for students (2007) emphasized: creativity and innovation; communication and collaboration; research and information fluency; critical thinking, problem solving, and decision making; digital citizenship; and technology operations and concepts.

Joannis M. Miaoulis (2009) claimed that the way to harness the creativity of young minds and fuel innovation of new technologies, is to use the engineering and design process as students explore the technological world, instead of the natural world, that most school science explores today.

> *Students need to be allowed to use their creativity to create a solution to a given challenge or problem.*

The ISTE framework for students (2007) emphasized: creativity and innovation; communication and collaboration; research and information fluency; critical thinking, problem solving, and decision making; digital citizenship; and technology operations and concepts.

The ISTE standards and performance indicators for teachers call for teachers to: facilitate and inspire student learning and creativity; design and develop digital-age learning experiences and assessments; model digital-age work and learning; promote and model digital-age citizenship and responsibility; and engage in professional growth and leadership.

The 21st Century Skills Map fuses the core academic areas along with communication, critical thinking, creativity, and collaboration, (the four C’s)

Scott Aronowitz (2010) noted that the Partnership for 21st Century Skills group advocates for /challenge based learning as the most effective change that can be made to America’s schools today.

Katehi, Pearson, Feder (2007) noted that K-12 engineering education should emphasize the design process, be incorporated into important and developmentally appropriate mathematics, science, and technology skills, and promote engineering habits of mind: systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations.

Building student skills.

Lack of knowledge or discipline to fully document thought processes.

The ISTE standards and performance indicators for teachers (2008) called for teachers to: facilitate and inspire student learning and creativity; design and develop digital-age learning experiences and assessments; model digital-age work and learning; promote and model digital-age citizenship and responsibility; and engage in professional growth and leadership.

Wenning (2005) pointed out the need for teachers to explicitly model each of the levels of inquiry for students, modeling appropriate actions and then fading from the scene allowing students to implement the modeled inquiry processes.

Hammerman (2006) noted that the quality of lessons guiding the teaching and learning process remains a key factor in increasing student achievement. Instruction must focus on important goals and standards and research based effective practices in order to improve student achievement.

Students want to spend more time exploring a topic or project in depth.

The La Vista Junior High School Improvement Team developed specific questions to guide staff in the attainment of the building wide goal of improving problem solving abilities of students. They brought up the following questions:

1. *How can we support instruction that focuses on conceptual understanding?*
2. *What are we doing to enhance and insure equity of learning experiences for all students?*

3. *What can be done to encourage teachers to emphasize the "how" and "why" over the "what" of instruction?*
4. *What can be done to address teachers' skepticism about best practices in instruction?*
5. *How can we foster teachers' development of higher level questioning and scaffolding for student learning?*

The ISTE standards and performance indicators for teachers (2008) call for teachers to: facilitate and inspire student learning and creativity; design and develop digital-age learning experiences and assessments; model digital-age work and learning; promote and model digital-age citizenship and responsibility; and engage in professional growth and leadership.

Prensky (2006) noted that educators need to listen to their students and value their opinions, making changes on the basis of their suggestions.

Cantrell et al (2006) developed a Triangulated Learning Module which involves a major question to generate the learning activity and is focused on how to make a system work. The iterative process requires evidence, explanations, and connections to scientific and mathematical knowledge.

Transferable skills develop with opportunities for repeated real world practice.

Robin Shoop (2005) noted that as students make cross curricular connections, they will synthesize new knowledge into many academic disciplines and learn to see how science and technology control the world in which they live. The National Academy of Engineering and the National Research Council (2009) note: when a school subject is taught, there should be a connection to the practice of that skill in the real world.

The ISTE framework for students (2007) emphasized: creativity and innovation; communication and collaboration; research and information fluency; critical thinking, problem solving, and decision making; digital citizenship; and technology operations and concepts.

Sadler, P. M. et al (2000) stated that design challenges provide opportunities to practice transferring new understandings to new situations and provide a way to make sense of how things work.

Joannis N. Miaoulis (2009) indicated that the key to getting our students to thrive in the global economy is to introduce students to engineering design skills and concepts that will allow them to apply their mathematical and scientific knowledge to solve real problems.

Practicing skills similar to those being assessed develops confidence and ability.

Katehi, Pearson, Feder (2007) noted that K-12 engineering education should emphasize the design process, be incorporated into important and developmentally appropriate mathematics, science, and technology skills, and promote engineering habits of mind: systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations.

Expected Results?

The results of the robotics data were not as convincing as I would like to have seen. First, some of the questions used in the content portion of the test had nothing to do with the activities students were involved in. The assessment really needed to be changed, so that each of the questions students were being asked to respond to related in some way to the activities they were presented with. It would be helpful if the data used would also be meaningful to students, so they had proof of how much they had grown from the beginning of the unit to the end. In some ways this is much like any other data gathering for proof of student learning.

Students really need to be encouraged to track their learning progress as well, through notebooks and journals, as well as various forms of quantitative data. Self reflection can often times tell a researcher more than an answer to a question on a test.

Next steps.

Moon challenge touchdown activity (when presented again).

a. Previous Feedback /criteria needs to be set for expectations in written reports.
b. Students must understand the iterative process, and the need to be specific about the each change to be made in their redesign.
c. Consider being a part of the science team helping to develop a new way to "do science" and help support students and teachers in the process.
d. If I were part of an entire science unit and not just a one day event, I would be more effective in making change in scientific behavior for students and teachers.

Robotics challenges (when presented again)**.**

a. Allow more time to work through the robotics challenges.
b. Possibly have a separate elective course for students who are willing to spend the entire course working on robotics rather than dabbling in several short tech ed. projects.
c. Have their solutions tied to a competition to see the best ideas incorporated into the design to take to contest level.
d. Create an online space for students to record their progress and problems they are working through, so they can put their heads together with other like minds to come up with the best solution to the problem they are working on.

Conclusion and Implications for Study

Summary of Findings

Three major themes came out of the results of analyzing the data from this action research study. The first was that of student engagement, in which students were more successful and more engaged in the learning process when the activities were presented as a design challenge to be solved by the students, and when they had several opportunities to repeat a process in order to become efficient in resolving the task at hand. I tie this first theme to the idea of:

- Hands On = Minds On / Engaged Learners
- Opportunities for Repeated Real World Practice Develop Transferable Skills

The second major theme was that involving the creativity of students to solve problems. Students have many ways to solve a given challenge or problem, and want to be allowed and encouraged to use it. I tie this second theme to the idea of:

- Many Possible Alternative Solutions to a Given Problem

The third major theme was that involving the students need to build skills to prepare them to be successful in school and in life. Many students lack the knowledge or skills necessary when trying to work through the activities that were a part of this study. Students did not have a clear grasp on how to document their progress and thinking as they worked through the *On the Moon Challenge: TouchDown*. As students worked through the robotics challenges they clearly were missing some important problem solving skills: trying a new method when another one didn’t work, breaking down a complex problem into smaller steps, carefully analyzing a problem before beginning on a solution. I tie this third theme to the idea of:

- Lack of Knowledge or Discipline to Fully Document Thought Processes
- Lack of Adequate Problem Solving Skills
- Students Wanting Explore a Topic or Project in Depth Before Moving on to Something New

Implications for future practice and / or research.

We must continue to document the progress we are making with students using robotics and the engineering and design process. Blumenfeld, et al (2000) suggested that curriculum units be designed to last between eight and 12 weeks allowing students opportunities to construct knowledge by solving real problems through asking and refining questions, designing and conducting investigations, gathering, analyzing, and interpreting information and data, drawing conclusions and reporting findings. Further evidence is needed to support the notion that robotics activities provide a rich context for students to identify and investigate problems, generate hypotheses, gather and analyze data, and to determine findings and interpret results. We need quantitative data measuring the direct impact of the robotics and engineering and design activities on the student learning outcomes.

Studies that explicitly measure scientific inquiry skills as an outcome of a robotic intervention still need to be completed. Other data gathering information concerning specific scientific, mathematical, and technological skills gained as a result of working through robotics and the engineering design process is also needed. To date, the length of time the robotic activities have been studied has been a relatively short period of time. Studying the results from an entire unit or elective course may shed more light on long term learning effects.

The results of this study support the findings of the body of knowledge reviewed in the literature. Much work still needs to done to validate the ideas that have been brought forth as a result of this study.

Questions still needing further research.

- What are ways to convince others of the need for more STEM type activities in our learning plans for students?
- As students make cross disciplinary connections, will they synthesize new knowledge for themselves and begin to understand how science and technology control the world in which they live?
- How can the engineering and design process be used as a context for exploring science, technology, and mathematics concepts and also promote engineering habits of mind.
- How can science inquiry and mathematical reasoning be connected to the engineering design process in K-12 curricula and teacher professional development?
- How can content in K-12 engineering be defined and designed in a rigorous and systematic way?

The Fire Project at Carnegie Mellon, Nebraska 4-H, and UNO's CEENBot will help to address some of the questions above in the upcoming months and years.

Personal Reflection

Learning process.

The action research project is one of the most all encompassing projects I have ever taken on. It has been a great journey and has definitely solidified my philosophy and teaching practice.

Most interesting component.

It was very difficult trying to manage the project into something that was not too time consuming. Each stage of the project took many more hours than I ever would have anticipated.

Most challenging aspect of the project.

For me the greatest difficulty was keeping the whole process in perspective. It became a "beast of its own" with no way of taming. Thorough synthesis and analysis of the literature and followed by synthesizing various facets of your own teaching craft, can be mind boggling.

Usefulness of the process for improving teaching and learning.

This is definitely a good use of professional development that I think will influence teachers in the way they teach for the rest of their career. This type of work definitely helps inform your practice as an educator.

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Appendix 1

School	Total 7-8	Free	Reduced	Free and Reduced	Female /Male	% F to % M
La Vista Jr	620	95= 15%	44=7%	139=22.4 %	7th 153 165 8th 152 150	48% 52% 50.3% 49.7%

Date as of: 10/1/2009	American Indian/Alaska Native		Asian or Pacific Islander		Black, Not Hispanic		Hispanic		White, Not Hispanic		Total
Total	**8**=1%		**12**=Almost 2%		**31**=5%		**43** =Almost 7%		**526**= Almost 85%		**620**
Total	**Female 5**	**Male 3**	**Female 5**	**Male 7**	**Female 15**	**Male 16**	**Female 17**	**Male 26**	**Female 263**	**Male 263**	**620**
Seventh Grade	Female 0	Male 1	Female 3	Male 2	Female 6	Male 9	Female 13	Male 16	Female 131	Male 137	318
Eighth Grade	Female 5	Male 2	Female 2	Male 5	Female 9	Male 7	Female 4	Male 10	Female 132	Male 126	302

Info taken from: *Membership Report from NSSRS*. Rep. no. 77-0027. NE Dept. of Educ., 2009-2010. Print.
http://www.paplv.org:8080/FedState%20Reports/Forms/AllItems.aspx

- ✓ 22.4% Free and Reduced lunch.
- ✓ 15% Free Lunch and 7% Reduced Lunch

- ✓ Almost 85% White, Not Hispanic
- ✓ Almost 7% Hispanic
- ✓ 5% Black, Not Hispanic
- ✓ 1% American Indian/Alaska Native
- ✓ Almost 2% Asian or Pacific Islander

- ✓ 50.8% male (315), 49.2% female (305)
- ✓ 48.7% eighth graders
- ✓ 51.3% seventh graders

Appendix 2

Copy of email seeking permission to use the ISTE standards

Re: Permissions, Renae Kelly, NETS.S, T, NASA report, NE

Tina Wells [twells@iste.org]

Sent: Friday, April 30, 2010 1:54 PM

To: Kelly, Renae

Dear Renae Kelly,

Thank you for your request for permission to use ISTE's National Educational Technology Standards for Students and Teachers.

As long as your usage is noncommercial, not for profit, and for educational purposes only, you have our permission to use the NETS.S and NETS.T for the report described below. The rights granted herein are non-exclusive, non-transferable, electronic and print rights only.

If the NETS are altered, then 1) you must not call your adaptation NETS and 2) you must indicate where the complete (unaltered) NETS can be found. (Minor altering of format is permissible.)

Please use the following credit lines in all uses of the material:

NETS for Students:
National Educational Technology Standards for Students, Second Edition, ©2007, ISTE® (International Society for Technology in Education), www.iste.org. All rights reserved.

NETS for Teachers:
National Educational Technology Standards for Teachers, Second Edition ©2008, ISTE® (International Society for Technology in Education), www.iste.org. All rights reserved.

For Web viewing, you are free to link to the NETS. We prefer that you link to this material rather than
posting: NETS.S: http://www.iste.org/Content/NavigationMenu/NETS/ForStudents/2007Standards/NETS_for_Students_2007.htm
NETS.T:
http://www.iste.org/Content/NavigationMenu/NETS/ForTeachers/2008Standards/NETS_for_Teachers_2008.htm If linking does not meet your needs, you have our permission to post the NETS on your website as long as the NETS are posted in full and are properly credited.
Please let us know if we can be of additional assistance. We wish you every success with your project.

Best regards,

Tina Wells
Book Production Editor
Rights & Permissions
International Society for

Technology in Education
541.434.8925

twells@iste.org

On Apr 27, 2010, at 11:38 AM, <rkelly@paplv.org> <rkelly@paplv.org> wrote:
A request to reprint ISTE material came in from Renae Kelly.

Company/Organization: NASA Endeavor Program
Member Number or Affiliate Name:Cohort # 1 Renae Kelly
Title:High Ability Learner Facilitator
Street Address:La Vista Junior High,7900 Edgewood Blvd
City:La Vista
State:NE
ZIP/Postal:68128
Country:USA
e-mail:rkelly@paplv.org
Phone:402-898-0436
Fax:402-898-0442

Requested ISTE Material:
Title/Description: National Education Technology Standards and Performance Indicators for Students and Teachers
Author(s)/Editor(s):International Society for Technology in Education),
Page/Figure/Table Number(s):

About the Project:
The ISTE material will appear in a(n) :Study
URL: Password:
Other:
Title of project: Robotics and the Engineering Designing Design Process: Motivating Students in the Digital Age
Author(s)/Editor(s) of project: Renae Kelly
Publisher: NASA Endeavor Project
Estimated publication/distribution date: Fall 2010
Number of Pages: 10-15
Number of copies:
For sale?:no
Project Price:
Presented at a speaking engagement?: no
Will ISTE Material be adapted or abridged?: yes

Other pertinent information: I would like to use your standards and performance indicators for students and teachers, as part of my literature review for my action research project. As of now it is just to submit for coursework, but we are also going to be encouraged to present our findings to others and therefore, I am seeking permission to use your documents prepared for students and teachers, for use in my report.

On Apr 27, 2010, at 11:46 AM, Kelly, Renae wrote:

Below please find the adaptation I made to your original document. Most of the changes are in format only and not words.

Sincerely,
Renae Kelly

The ISTE National Educational Technology Standards (NETS•S) and Performance Indicators for Students
1. Creativity and Innovation
Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students:
a. apply existing knowledge to generate new ideas, products, or processes.
b. create original works as a means of personal or group expression.
c. use models and simulations to explore complex systems and issues.
d. identify trends and forecast possibilities.
2. Communication and Collaboration
Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.
Students:
a. interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.
b. communicate information and ideas effectively to multiple audiences using a variety of media and formats.
c. develop cultural understanding and global awareness by engaging with learners of other cultures.
d. contribute to project teams to produce original works or solve problems.
3. Research and Information Fluency
Students apply digital tools to gather, evaluate, and use information.
Students:
a. plan strategies to guide inquiry.
b. locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
c. evaluate and select information sources and digital tools based on the appropriateness to specific tasks.
d. process data and report results.
4. Critical Thinking, Problem Solving, and Decision Making
Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and

make informed decisions using appropriate digital tools and resources.

Students:

a. identify and define authentic problems and significant questions for investigation.

b. plan and manage activities to develop a solution or complete a project.

c. collect and analyze data to identify solutions and/or make informed decisions.

d. use multiple processes and diverse perspectives to explore alternative solutions.

5. Digital Citizenship

Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.

Students:

a. advocate and practice safe, legal, and responsible use of information and technology.

b. exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.

c. demonstrate personal responsibility for lifelong learning.

d. exhibit leadership for digital citizenship.

6. Technology Operations and Concepts

Students demonstrate a sound understanding of technology concepts, systems, and operations.

Students:

a. understand and use technology systems.

b. select and use applications effectively and productively.

c. troubleshoot systems and applications.

d. transfer current knowledge to learning of new technologies.

Appendix 3A

The Design Notebook of Renae Kelly

1. **Identify the problem**

How can I design a spacecraft that will absorb the shock of landing enough to keep two "astronauts" safely inside the craft as it lands? How will I slow it down first, and then how can I get it to "softly or gently" touch down on the landing surface?

2. **Brainstorming**
   "If _____ [I do this] ________, then __________ [this] _____ will happen."

What kind of shock absorber can I design? Do I need large springs or smaller ones?
If I fold the shocks with six sections across the length of the card, ___________will happen.
If I fold the shocks with seven sections across the length of the card, __________will happen.

How can I make sure the craft remains upright and does not tip over upon landing?
If I create a triangle base using three straws and attach the shocks to the straws, then the craft lands upright almost every time I drop it.

3. **Design**

I can tape the triangle straw platform to each of the three shocks and then attach the other end of the shocks to the cardboard platform.

Next I will add the straw streamers to the cabin by poking five holes spaced evenly across the bottom of the upper rim of the glass.

Then I will add cabin and the straw streamers (as thought of in a redesign of the first solution) to the top of the cardboard platform using a rolled up piece of masking tape on the bottom of the cup, and supporting the cup with additional tape touching the sides of the cup and the top of the cardboard platform.

4. **Build**

It appears that the shock absorber with seven sections was superior to the one with only six sections, so I will attach the seven section absorber to the straw platform

Step 1: Fold the three index cards with seven equal sections folded in a back and forth format **.**
Step 2: Create a triangle shape using three straws, slipped inside another straw where the two ends meet. Tape down, to secure the joint.
Step 3: Tape the ends of each shock absorber to the middle of the cardboard platform, creating a triangle shape with the edges of the three shock absorbers and secure with tape.
Step 4: Tape the other ends of each shock absorber (index card) to one of the straw platform triangle sides so that each shock is in the middle of one side of the triangle, with one shock connected to one side of the triangle.
Step 5: Using a pencil, poke five equidistant holes in the bottom of the upper rim of the Styrofoam cup and insert a plastic straw end from the outside of the cup, and tape down the

two to two and a half inches of the straw inside the cup to the side of the cup in order to keep the excess straw pieces inside the cup out of the way.
Step 6: Bend the straws so that they are angling about 45 degrees from the upper edge of the cup.
Step 7: Attach the cup (cabin) to the cardboard platform with a loop of tape on the bottom of the cup, so that is exactly at the center of gravity in order to land in an upright position. Secure it with more strips of tape on the sides of the cup and on the top of the cardboard platform.
Step 8: Set two astronauts inside the cabin of the spaceship. Secure with the rubber bands hooking onto each of the straw streamers and then across to the opposite side of the cup and straw streamer on that side. Secure with tape to keep the rubber bands from slipping out of place.
Step 9: Launch and watch your spaceship land safely upright, with the astronauts safely inside the spacecraft the entire time.

5. Test and Evaluate

Each time I dropped the cardboard platform with the shocks and landing support attached to it, it landed upright, but fell at a fairly fast speed. It was then that I decided I must find a way to slow it down and thought of adding the streamers of straws from the cabin of the aircraft.

Dropping the redesigned spacecraft with the straw streamers, it consistently landed fairly gently and upright each time, without ever ejecting any of the astronauts.

6. Redesign

What can I add to the craft to help it slow down as it prepares to land?

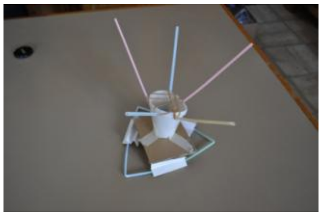
Can I find a way to use some of the straws as "streamers" to slow the speed down as it is dropped from greater heights, so that the landing is more smooth?

How might I be able to make use of the three rubber bands and mini-marshmallows that were included in the materials list?

If I use the rubber bands to cross over the top of the cabin, attaching to the straw streamers, I can be more assured that the astronauts will not bounce out of the cabin and will remain safe.

If I use the miniature marshmallows as landing gear on the straw landing platform, it may be able to soften the landing even more. I would tape one in each corner of the triangle and then tape two more on each of the sides, sharing equal distance between each of the marshmallows.

7. Share the solution



My Prototype

Appendix 3B

(Student Examples of the Analyzed Categories)

1. **Complete and Thorough Documentation:**

1\05\10
Period 3

(*) Challenge
- to create a ~~spacecraft~~ Safe spacecraft

Excellent

(*) Brainstorm
- shockabsorbing
  - use soft moshmellows
  - wind "catcher"
- doesn't tip over
  - make sure weight is even

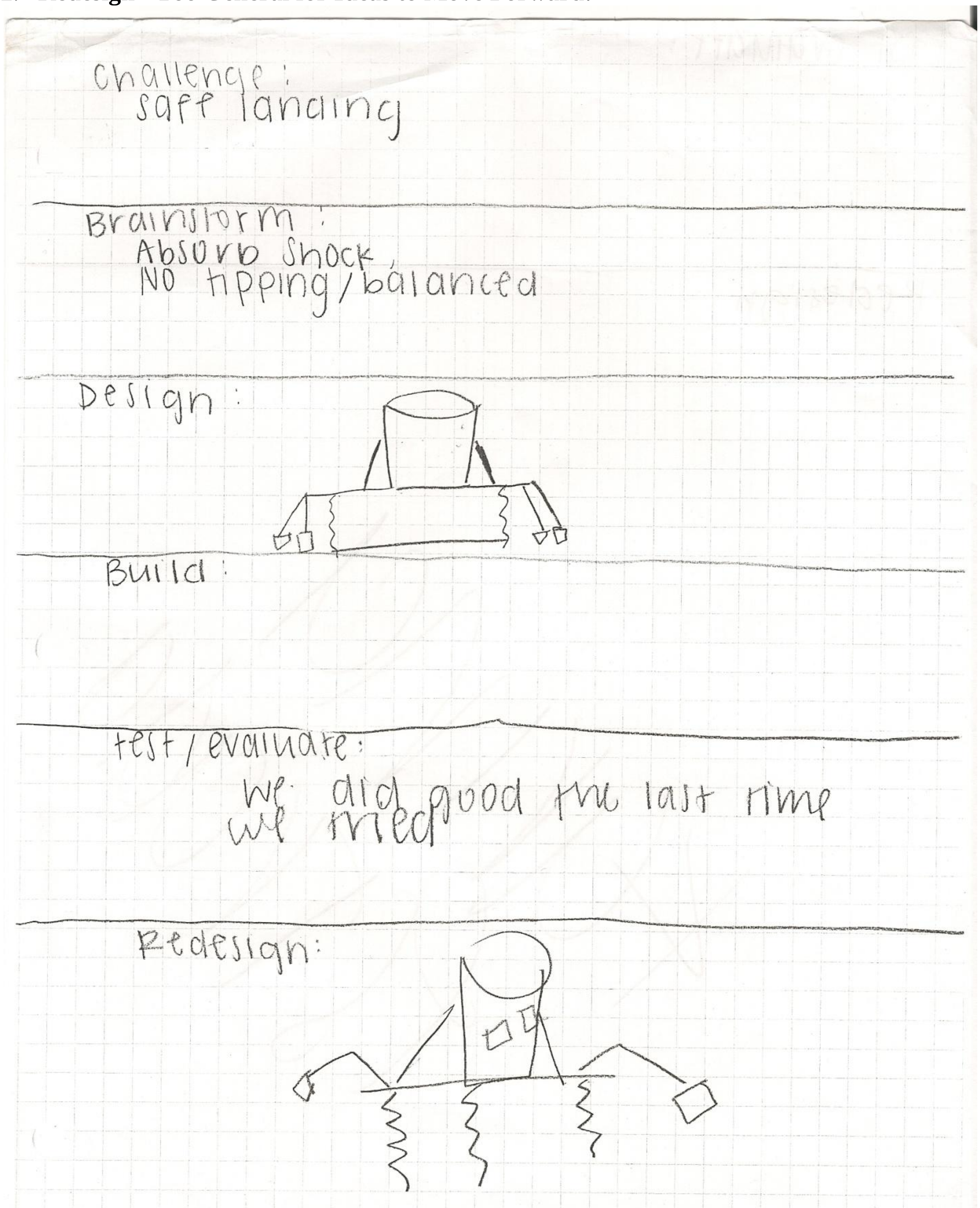
(*) Design

(*) Build
- put cup on cardboard \ taped
- add notecards
- add marshmellows
- added straws

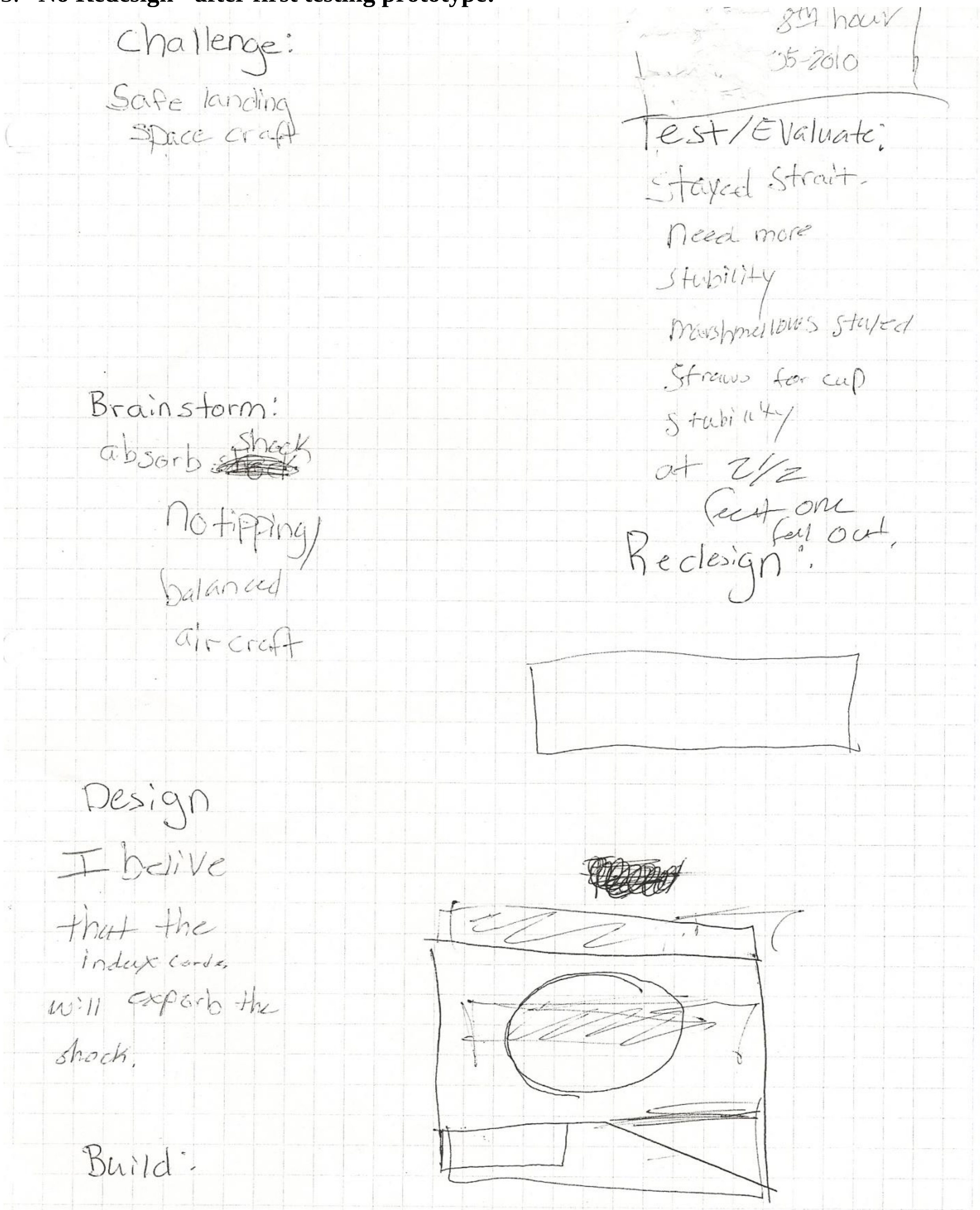
(*) Test\ Evaluate
- lands upright
  - no marshmellows fell out
- table - 1 fell out \ landed up

(*) Redesign
- add straws
  - push marshmellows down

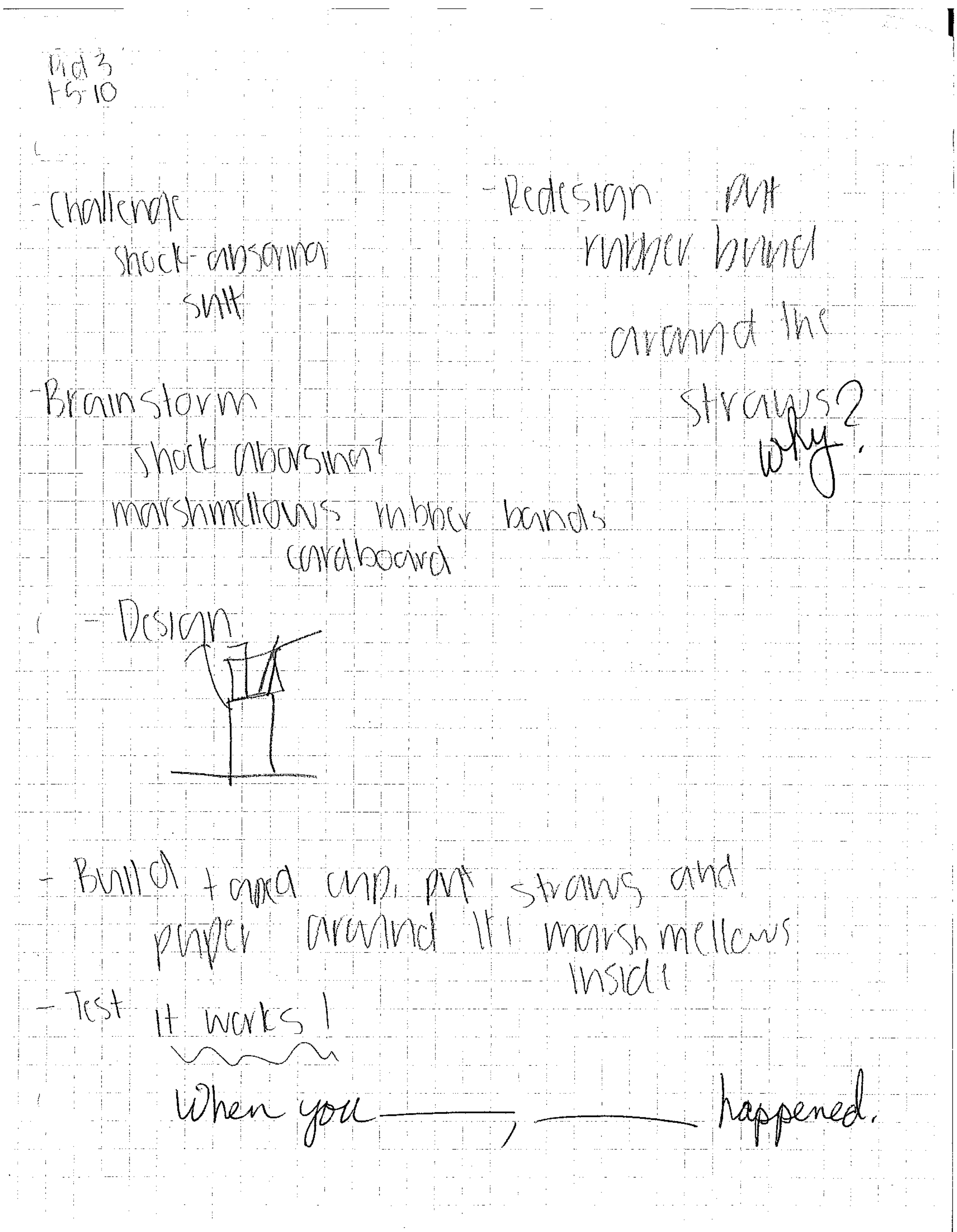
2. **Redesign - Too General for Ideas to Move Forward:**



3. **No Redesign - after first testing prototype:**



4. **Incomplete report, important documentation missing:**



Appendix 3C

Parental Permission Form Photo Release

Endeavor
Science Teaching Certificate Project

Sponsored by:
National Aeronautics
and Space Administration
(NASA Award NNX08BA63A)

TEACHERS COLLEGE
COLUMBIA UNIVERSITY

Parental Permission Form

MUST be ***signed and copies returned or faxed*** *in order for student to participate to the address below.*

==

Photo Release

During participation in the NASA Endeavor Science Teaching Certificate Project, teachers photograph and/or videotape participants and events to record special moments. We request your permission to use these pictures for NASA Endeavor as well as NASA-related educational outreach. Images or video may be used in print materials or on websites, but would only be used for NASA Endeavor or NASA-related efforts. Students' names will NOT be listed.

The NASA Endeavor Science Teaching Certificate Project has my permission to use photographs or videos of my child in online and print materials.

Nathan Wiesor
student's name, please print

parent / guardian signature

==

Teachers Fax or mail originals to:

NASA Endeavor Science Teaching Certificate Project c/o
U.S. Satellite
32 Elm Place, 1st Floor
Rye, NY 10580

Endeavor
Science Teaching Certificate Project

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and Space Administration
(NASA Award NNX08BA63A)

TEACHERS COLLEGE
COLUMBIA UNIVERSITY

Parental Permission Form

*MUST be **signed and copies returned or faxed** in order for student to participate to the address below.*

==

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Amber Vacek ______ Glenda Vacek ______
student's name, please print parent / guardian signature

==

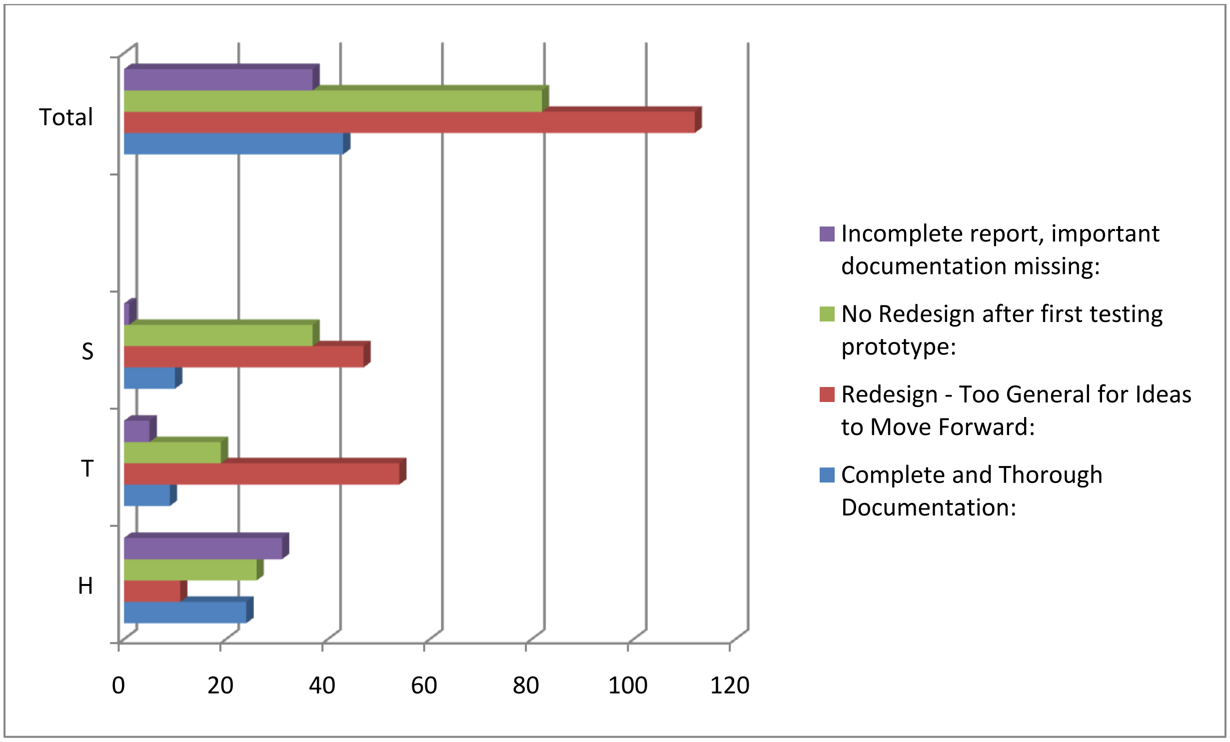
Teachers Fax or mail originals to:

NASA Endeavor Science Teaching Certificate Project c/o
U.S. Satellite
32 Elm Place, 1st Floor
Rye, NY 10580

Appendix 3D

Engineering Notebook Analysis Results

Categories	H	T	S	Percentage	Total
Complete and Thorough Documentation:	24	9	10	15.7%	43 total
Redesign – Too General for Ideas to Move Forward:	11	54	47	40.9%	112 total
No Redesign after first testing prototype:	26	19	37	29.9%	82 total
Incomplete report, important documentation missing:	31	5	1	13.5%	37 total



S = Hurricanes Team

T = Cyclones Team

H = Lightning Team

Appendix 4A

Email Communications Documenting Permission to Use Copyrighted Material

Copy of email seeking permission to use the

NE 4-H Robotics Content Quiz and Attitudinal Questionnaires

RE: December report data instruments
Sent: Monday, March 22, 2010 9:22 AM

To: Bradley S Barker [bbarker@unlnotes.unl.edu]

Thank you so much, Brad. That is exactly what I needed. After the results are pulled together from my study, I will share them with you.

Renae

From: Bradley S Barker [mailto:bbarker@unlnotes.unl.edu]
Sent: Monday, March 22, 2010 9:19 AM
To: Neal Grandgenett
Cc: bchen@mail.unomaha.edu; elliottostler@mail.unomaha.edu; Kelly, Renae
Subject: Re: December report data instruments

Hi Renae,

Attached is the exam answer sheet. Let me know if you have any questions.

Best,
Brad

Bradley S Barker, Ph.D.
Assistant Professor
4-H Youth Development
University of Nebraska-Lincoln
114 Agricultural Hall, Lincoln, NE 68583-0700
Office: (402) 472-9008
Fax:(402) 472-9024
bbarker@unl.edu

RE: December report data instruments
Sent: Monday, March 22, 2010 7:57 AM

To: Neal Grandgenett [ngrandgenett@mail.unomaha.edu]

Thank you so much Neal. I will get you a copy of my results when I have that part completed.

Renae

-----Original Message-----
From: Neal Grandgenett [mailto:ngrandgenett@mail.unomaha.edu]
Sent: Sunday, March 21, 2010 8:58 PM
To: Kelly, Renae
Cc: bbarker@unlnotes.unl.edu; bchen@mail.unomaha.edu; elliottostler@mail.unomaha.edu
Subject: Re: December report data instruments

Hi Renae,
You are more than welcome to use the instruments. The NSF requires us to share these sorts of things, but thanks for asking. As you mentioned, the content/attitude assessments referenced are actually 4H Robotics and GIS/GPS instruments which is officially part of Brad's project, but I am pretty sure that he won't mind either, especially if we can get a copy of your completed research, etc. Right Brad? We primarily used the
instruments in SPIRIT as part of a shared control group/short intervention effort with 4H Robotics.

Brad, if you remember, you met Renae in Papillion LaVista, at the PLV meeting about a year or two ago with you, I, and Gwen, when Renae and several other administrators there at PLV about doing something like she is doing now (among other ideas)? It is nice to see you moving forward with some of your ideas Renae.

By the way Renae, the content tests are being revised, but unfortunately they won't be done by the time that you need them. Your curriculum may not be as well aligned with the these particular tests, but it is worth a try. Those tests are unfortunately the best that we have for now.

Brad, do you have the key to the content test handy by chance, that you can forward to Renae?

Renae, best wishes on your research. Those of us working on the NSF robotics projects (SPIRIT and 4H) love to see others try to collect and summarize research data, which we can in turn share as a positive result to
NSF. We are glad you are working in this effort.

Best wishes, and again, thanks for trying to further some of our work...that is neat.
Neal (on behalf of Brad, Bing, and Elliott)

From: "Kelly, Renae" <RKelly@paplv.esu3.org>
To: <ngrandgenett@mail.unomaha.edu>, <bchen@mail.unomaha.edu>,
<elliottostler@mail.unomaha.edu>
Cc: <bbarker@unlnotes.unl.edu>

Date: 03/21/10 10:05 AM
Subject: December report data instruments

Dr. Grandgenett, Dr. Chen, and Dr. Ostler,

I am writing to you seeking permission to use the data gathering instruments you shared in the Dec 2009 report for:

Project Evaluation Report - Year 2 December 20,2009
Silicon Prairie Initiative for Robotics in Information Technology 2.0
SPIRIT 2.0

I specifically would like to use the pre and post tests and questionnaires you used in your evaluation, since they have already been shown to be valid and rigorous. I would also like to use the engineering notebook setup you included in the same report.

Is it possible to have the key for the concept test questions? I think I have most of the answers correct, but want to be sure they match what you were looking for in your research.

I am doing action research for my NASA Endeavor STEM endorsement, seeking to find the answer to the question: Do robotics and the engineering design process increase student motivation and achievement in attaining STEM concepts in students?

I have compiled your survey and test questions into an online format, so it will be easier to analyze the data I collect. I am enclosing the links to those instruments below.

Pretests:

4-H Robotics and GPS/GIS and SPIRIT Interest Questionnaire - Pre
http://freeonlinesurveys.com/rendersurvey.asp?sid=ecncqjweebdpelx723967
<http://freeonlinesurveys.com/rendersurvey.asp?sid=ecncqjweebdpelx723967>

Robotics Workplace Skills Youth Questionnaire - Pre
http://freeonlinesurveys.com/rendersurvey.asp?sid=v35mc9yjwwdjd95723956
<http://freeonlinesurveys.com/rendersurvey.asp?sid=v35mc9yjwwdjd95723956>

Nebraska 4-H Robotics : GPS/GIS and SPIRIT Content Quiz - Pre
http://FreeOnlineSurveys.com/start.asp?sid=9jnhr0uhdoebk64723934
<http://freeonlinesurveys.com/start.asp?sid=9jnhr0uhdoebk64723934>

Posttests:

Nebraska 4-H Robotics : GPS/GIS and SPIRIT Content Quiz - Post
http://FreeOnlineSurveys.com/start.asp?sid=jilak26sdw0jl1l727650

<http://freeonlinesurveys.com/start.asp?sid=jilak26sdw0jl1l727650>

Robotics Workplace Skills Youth Questionnaire (Post)
http://FreeOnlineSurveys.com/rendersurvey.asp?sid=tfgoa479cszn6my727654
<http://freeonlinesurveys.com/rendersurvey.asp?sid=tfgoa479cszn6my727654>

4-H Robotics and GPS/GIS and SPIRIT Interest Questionnaire - Post
http://FreeOnlineSurveys.com/rendersurvey.asp?sid=409n9icx1pbkv8x727655
<http://freeonlinesurveys.com/rendersurvey.asp?sid=409n9icx1pbkv8x727655>

Curriculum Surveys:

Curriculum Pilot Testing: Teacher Facilitator Feedback Survey
http://FreeOnlineSurveys.com/rendersurvey.asp?sid=jokw3cmtdmv2up9723915
<http://freeonlinesurveys.com/rendersurvey.asp?sid=jokw3cmtdmv2up9723915>

Curriculum Pilot Testing: Student Feedback Form
http://FreeOnlineSurveys.com/rendersurvey.asp?sid=yxdt87cqatbjufy723923
<http://freeonlinesurveys.com/rendersurvey.asp?sid=yxdt87cqatbjufy723923>

Thanks so much for your help on this. I am hoping to administer the pretests this week and then work with the students the first week or two in April, followed by administering the post assessments. Our school will be on spring break the last week in March, so in order to get the survey done a week or so before the activities, it will need to be done this week.

I would like to use the student and teacher curriculum survey you enclosed in your report, as I work through each lesson. I was thinking of using lessons that are in the 4-H Robotics as my lessons, so that my research
could tie findings to what happens within the school setting, to what happens outside of the school setting (as in Bradley Barker's research).

Thanks for you help and support on this project. When completed, I would be happy to share my findings with you.

Sincerely,

Renae Kelly

Appendix 4B

Nebraska 4-H Robotics : GPS/GIS and SPIRIT Content Quiz – Pre (Post)

For each of the following questions, mark the corresponding letter of the answer that best answers the question.

Grandgenet, N. et al (2009, December). *Silicon Prairie Initiative for Robotics in Information Technology 2.0: Spirit 2.0 (National Science Foundation*. pg. 74-84. Retrieved from http://ceen.unl.edu/TekBots/SPIRIT2/Reports/SPIRIT2.0reportDec2009

1) Name:	
2) Elementary School attended:	
3) State	
4) Leader Name:	
5) Age:	
Multiple Choice: For each of the following questions, circle the letter of the answer that best answers the question.	
6) In order to follow a delayed sequence of set movements, without direct user control, a robot must be ______	
A. controlled by a remote.	
B. computerized.	
C. programmed.	
D. trained.	
7) A programming “loop” does which of the following?	
A. Starts the program code	
B. Stops the program code	
C. Performs multiple functions	

D. Repeats a section of program code	
8) A computer program consists of ______ that tells the computer to do something.	
A. sensors	
B. code	
C. lights	
D. robots	
9) Which of the following enables a robot to investigate and react to its environment?	
A. Tires	
B. Sensors	
C. LCD panels	
D. Mechanical arms	
10) What is a computer program?	
A. Computer generated text	
B. The hardware that controls a computer	
C. Instructions written in a language a computer understands	
D. Language that is built into a robot	
11) Which of the following is a wireless connection?	
A. Bluetooth	
B. RCX	
C. USB	
D. Serial port	

12) When programming your robot, a switch block or if/else/then statement is used to _____	
A. ask a question.	
B. stop the program.	
C. speed up the program.	
D. repeat the code.	
13) Which of the following is an example of multi-tasking?	
A. Having your robot move forward on a table	
B. Having your robot turn to the left for 2 seconds	
C. Having your robot measure a distance as it identifies an object to lift	
D. Having your robot use its light sensor	
14) The process of refining an instrument, like your robot, so that it is as accurate as possible by collecting information about how far your robot will travel in a given amount of time and using the information to estimate how long it will take the robot to go a given distance is called _____	
A. a ratio.	
B. the Pythagorean Theorem.	
C. a threshold value.	
D. calibration.	

Amie and Cody are engineers working to design a robot that will be able to plant trees in a fruit production orchard with apples, apricots, oranges and/or peaches. They need your help to apply the steps of the Engineering Design Process. Answer questions 15-18 below to provide your assistance.

Image of an apple orchard from Kelowna Land and Orchard Company Ltd. (KLO) in British Columbia, Canada. Image from http://media-cdn.tripadvisor.com/media/photos/00/11/f9/0a/orchard-at-kelowna-land.jpg used without permission.

Grandgenet, N. et al (2009, December). *Silicon Prairie Initiative for Robotics in Information Technology 2.0: Spirit 2.0 (National Science Foundation*. pg. 125. Retrieved from http://ceen.unl.edu/TekBots/SPIRIT2/Reports/SPIRIT2.0reportDec2009

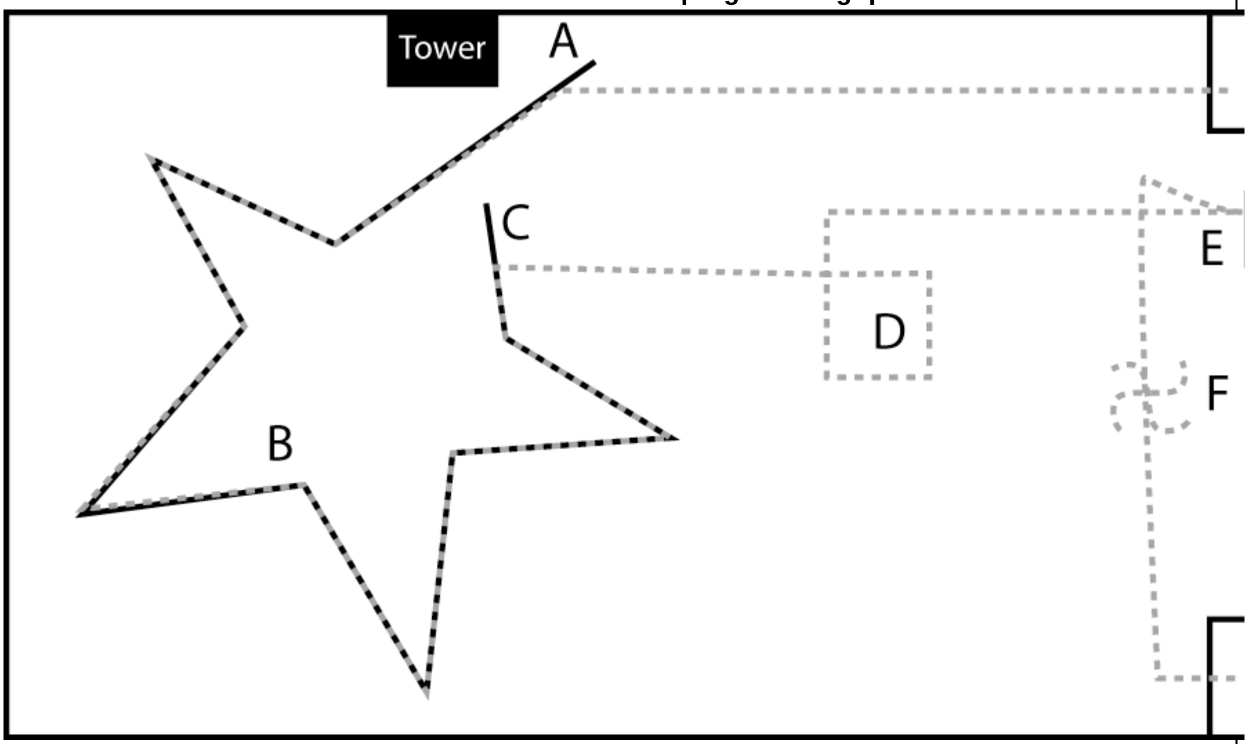
Use the photograph above to answer questions 15 through 18

15) Which of the following would not be part of the problem that Amie and Cody need to solve in order to begin designing their robot?

A. T robot must be able to travel in standing water.	
B. The robot must be able to avoid obstacles such as large rocks and existing trees.	
C. The robot must be able to go to a specific location, using GPS.	
D. The robot must be able to dig a hole.	
16) As a part of the design process, Amie and Cody visit an engineering library to look at existing patents. Which step in the Engineering Design Process are they doing?	
A. Identify the problem	
B. Research the problem	
C. Select a solution	
D. Construct a prototype	
17) Amie and Cody are reviewing the possible solutions to select one to test by building a prototype. Which of the solutions below do you think is most important to the project?	
A. The robot should operate quietly to lessen the disturbance to wildlife in the area.	
B. The robot should be on tracks to cover diverse terrains.	
C. The robot should have a camera so the operators can see what it is doing from anywhere with an Internet connection.	
D. The robot should have a robotic arm that can do tasks such as dig the hole, place the tree and replace the soil.	
18) Which of the following strategies would be important to evaluating Amie and Cody's solution?	
A. Testing the prototype by planting trees in different orchard settings or environments	
B. Asking other engineers on your team to review their design and prototype	
C. Check the design with specialized computer software to find potential flaws	
D. All of the above	

Technology – Robotic Programming

Use the obstacle course shown to answer the robot programming questions # 19 to 24 below.



Grandgenet, N. et al (2009, December). *Silicon Prairie Initiative for Robotics in Information Technology 2.0: Spirit 2.0 (National Science Foundation*. pg. 126. Retrieved from http://ceen.unl.edu/TekBots/SPIRIT2/Reports/SPIRIT2.0reportDec2009

19) The dashed line(s) show(s the path of the robot. The solid line is a black electrical tape one inch wide

A. Light	
B. Sound	
C. Touch	
D. Ultrasonic	

20) Which of the marked points on the image above corresponds to the pseudocode shown here:
Loop 4 times – Forward one tire rotation, Turn ninety degrees right

A. Point B	
B. Point D	

C. Point E	
D. Point F	
21) At point F, the robot spins counterclockwise for at least 1080 degrees. Which pseudocode line would cause the robot to turn 1080 degree?	
A. Forward, left motor 10 rotations	
B. Forward, right motor 10 rotations	
C. Forward turning to the left, left and right motors 10 rotations	
D. Forward turning to the right, left and right motors 10 rotations	
22) Which of the marked points in the image above corresponds to the pseudocode shown here: Wait until touch, reverse two wheel (720 degrees) rotations	
A. B	
B. D	
C. E	
D. F	
23) Which of the sensors listed would most likely not be used to complete this challenge?	
A. Light	
B. Sound	
C. Touch	
D. Rotation	
24) Which pseudocode is the most reliable way to program the robot at point C (find the tower and then turn, using an ultrasonic sensor) in the image above?	
A. Forward 2.3 wheel rotations to the tower	

B. Forward 828 degrees to the tower	
C. Forward 1.6 seconds to the tower	
D. Forward until 15 inches from the tower	

Appendix 4C

4-H Robotics and GPS/GIS and SPIRIT Interest Questionnaire – Pre (Post)
I am interested in learning about your attitudes towards science, technology, engineering, and mathematics. I particularly want to get your reaction to learning about robotics, which involves the building and programming of small robots.

I am also are interested in your attitudes about GPS (Global Positioning Systems) and GIS (Geographical Imaging Systems). GPS helps us record and use satellite data to understand geographical location and mapping concepts. GIS is a computer tool you can use to develop, analyze, and display geographic maps.

Grandgenet, N. et al (2009, December). *Silicon Prairie Initiative for Robotics in Information Technology 2.0: Spirit 2.0 (National Science Foundation*. pg. 74-84. Retrieved from http://ceen.unl.edu/TekBots/SPIRIT2/Reports/SPIRIT2.0reportDec2009

1) Name
2) State
3) Leader Name
4) Age
5) Gender
Male
Female
6) Ethnicity
African American
American Indian
Asian or Pacific Islander

Hispanic
White (non Hispanic)
Other (Please Specify):
Please give your perceptions on the following ideas using a 5 point Likert scale from Strongly Agree to Strongly Disagree. 7) It is important for me to learn how to conduct a scientific investigation.
8) It is important for me to learn about robotics.
9) It is important for me to learn how to use appropriate tools and techniques to gather, analyze and interpret data.
10) It is important for me to learn about GIS.
11) It is important for me to learn how to use mathematical formulas to help solve practical problems.
12) It is important for me to learn how to make accurate measurements to help solve mathematical problems.
13) It is important for me to be able to record measurements and calculations into tables and charts.
14) It is important for me to learn how to collect and interpret data to verify a prediction or hypothesis.
15) It is important for me to understand basic engineering concepts (e.g. design tradeoffs, speed, torque) related to building and moving a robot.
16) It is important for me to learn how to program a robot to carry out commands.
17) It is important for me to learn about GPS.
18) I like using the scientific method to solve problems.
19) I like learning new technologies such as robotics.
20) I like using mathematical formulas and calculations to solve problems.
21) I like learning new technologies like GPS.

22) I use a step by step process to solve problems.
23) I make a plan before I start to solve a problem.
24) I am confident that I can program a robot to move forward two wheel rotations (i.e. 720 degrees) and then stop.
25) I try new methods to solve a problem when one does not work.
26) I carefully analyze a problem before I begin to develop a solution.
27) In order to solve a complex problem, I break it down into smaller steps.
28) I am certain that I can build a robot by following design instructions.
29) I am certain that I can fix the software program for a robot that does not behave as expected.
30) I am certain that I can log locations of a series of waypoints within a GPS unit.
31) I am confident that I can program a robot to follow a black line using a light sensor.
32) I am confident that I can read and understand maps.
33) I am confident that I can make a digital map.
34) I am confident that I can use GPS technologies to get to places that I have never been before.
35) I like listening to others when trying to decide how to approach a task or problem.
36) I like being part of a team that is trying to solve a problem.
37) When working in teams, I ask my teammates for help when I run into a problem or don't understand something.
38) I like to work with others to complete projects.
39) I like learning new technologies such as GIS.
40) How interested are you in each of the jobs below for possible future careers? Scientist

41) How interested are you in each of the jobs below for possible future careers? Engineer
42) How interested are you in each of the jobs below for possible future careers? Mathematician
43) How interested are you in each of the jobs below for possible future careers? Computer or Technology Specialist
44) How interested are you in each of the jobs below for possible future careers? Job involving GPS/GIS

Appendix 4D

Curriculum Pilot Testing: Student Feedback Form (Post Only)

Form Purpose: Thank-you for trying out some of the robotics activities with me. I want to know what you learned, how you liked the robotics activities, and if you have any suggestions for their improvement. Your feedback will be kept confidential and will only used to make the activities better.

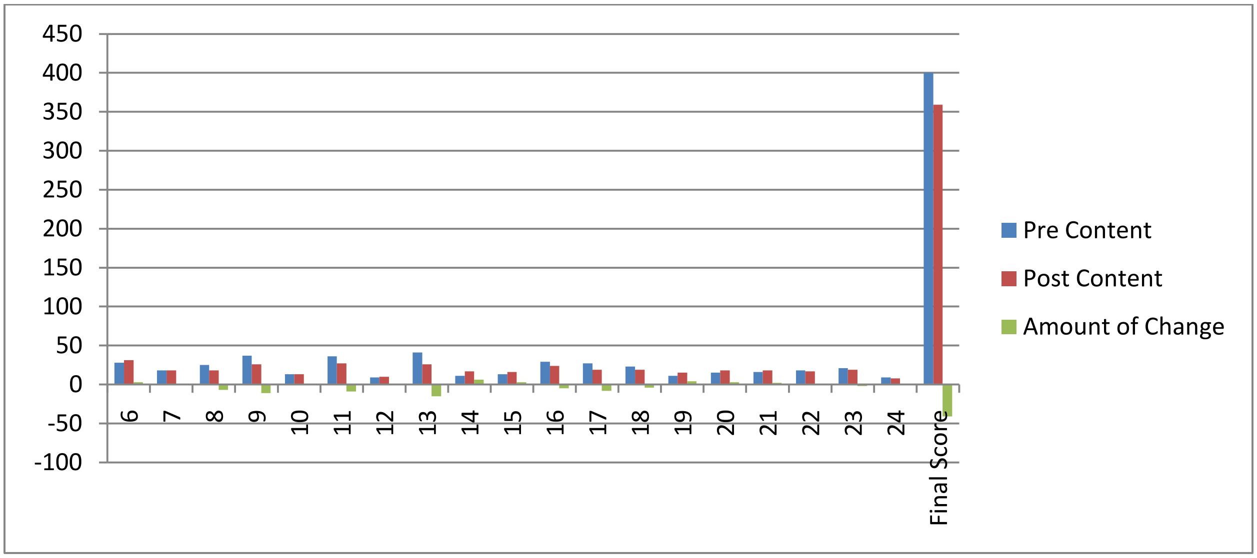
Grandgenet, N. et al (2009, December). *Silicon Prairie Initiative for Robotics in Information Technology 2.0: Spirit 2.0 (National Science Foundation*. pg. 74-84. Retrieved from http://ceen.unl.edu/TekBots/SPIRIT2/Reports/SPIRIT2.0reportDec2009

1) Reviewer/Facilitator Name:
2) Robotics Lesson/Activity Piloted:
3) Location Where Piloting Took Place:
Please give your perceptions on the different educational robotics lesson components using a likkert scale from *Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree*. 4) The lesson/activity helped me to learn about science or science concepts.
5) The lesson/activity helped youth to me to learn about technology or technology concepts.
6) The lesson/activity helped me to learn about engineering or engineering concepts.
7) The lesson/activity helped me to learn about mathematics or mathematics concepts.

8) I found the lesson or activity to be interesting.
9) I would tell my friends that the activity was a good one.
10) For you personally, what was the best part of the lesson? Why?
11) For you personally, how could the overall lesson or activity be improved?
12) Anything else to tell me about this activity?

Appendix 5A

Pre and Post Content Assessment Data



Contest Pre and Post Data

Final Score	Post		Final Score	Pre	
1			2		
2			2		
2			2		
2			3		
2			3		
2			3		
2			4		
3			4		
3			4		
3			4		
4			5		
4			5		
4			5		
4			5		
4			5		
4			5		
4			5		
5	Mean	6.648	6	Mean	7.407
5	Median	5	6	Median	7
5	Mode	5	6	Mode	7
5			6		
5			6		
5			7		
5			7		

5	7	
5	7	
5	7	median
6	7	
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12	11	
12	12	
12	12	
12	12	
13	12	
14	13	
15	14	
16	15	
16	17	
359	400	

Range: 15 (1-16) Range: 15 (2-17)

Four students answered at least 70% of the questions correctly on the post test, while only three students answered with a passing score on the pre test.

Appendix 5B

Results for: Nebraska 4-H Robotics : GPS/GIS and SPIRIT Content Quiz – Post

Question	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Final Score
Pre Content	28	18	25	37	13	36	9	41	11	13	29	27	23	11	15	16	18	21	9	400
Post Content	31	18	18	26	13	27	10	26	17	16	24	19	19	15	18	18	17	19	8	359
Amount of Change	3	0	-7	-11	0	-9	1	-15	6	3	-5	-8	-4	4	3	2	-1	-2	-1	-41

6) Multiple Choice: For each of the following questions, circle the letter of the answer that best answers the question.

1. In order to follow a delayed sequence of set movements, without direct user control, a robot must be ______

	Percentage	Responses
A. controlled by a remote.	13.2	7
B. computerized.	26.4	14
C. programmed.	**58.5**	**31 +3**
D. trained.	1.9	1
Total responses:		**53**

7) 2. A programming "loop" does which of the following?

	Percentage	Responses
A. Starts the program code	26.4	14
B. Stops the program code	24.5	13
C. Performs multiple functions	15.1	8
D. Repeats a section of program code	**34.0**	**18 +0**
Total responses:		**53**

8) 3. A computer program consists of _______ that tells the computer to do something.

	Percentage	Responses
A. sensors	47.2	25
B. code	**34.0**	**18 -7**
C. lights	11.3	6
D. robots	7.5	4
	Total responses:	**53**

9) 4. Which of the following enables a robot to investigate and react to its environment?

	Percentage	Responses
A. Tires	28.3	15
B. Sensors	**49.1**	**26 -11**
C. LCD panels	13.2	7
D. Mechanical arms	9.4	5
	Total responses:	**53**

10) 5. What is a computer program?

	Percentage	Responses
A. Computer generated text	19.6	10
B. The hardware that controls a computer	45.1	23
C. Instructions written in a language a computer understands	**25.5**	**13 +0**
D. Language that is built into a robot	9.8	5
	Total responses:	**51**

11) 6. Which of the following is a wireless connection?

	Percentage	Responses
A. Bluetooth	**52.9**	**27 -9**
B. RCX	23.5	12
C. USB	13.7	7
D. Serial port	9.8	5
	Total responses:	**51**

12) 7. When programming your robot, a switch block or if/else/then statement is used to _____

	Percentage	Responses
A. ask a question.	**18.9**	**10 +1**
B. stop the program.	39.6	21
C. speed up the program.	32.1	17
D. repeat the code.	9.4	5
	Total responses:	**53**

13) 8. Which of the following is an example of multi-tasking?

	Percentage	Responses
A. Having your robot move forward on a table	11.8	6
B. Having your robot turn to the left for 2 seconds	31.4	16
C. Having your robot measure a distance as it identifies an object to	**51.0**	**26 -15**

lift			
D. Having your robot use its light sensor		5.9	3
		Total responses:	**51**

14) 9. The process of refining an instrument, like your robot, so that it is as accurate as possible
by collecting information about how far your robot will travel in a given amount of time
and using the information to estimate how long it will take the robot to go a given distance
is called _____

		Percentage	Responses
A. a ratio.		30.2	16
B. the Pythagorean Theorem.		22.6	12
C. a threshold value.		15.1	8
D. calibration.		**32.1**	**17 +6**
		Total responses:	**53**

15) Amie and Cody are engineers working to design a robot that will be able to plant trees in a fruit
production orchard with apples, apricots, oranges and/or peaches. They need your help to apply
the steps of the Engineering Design Process. Answer the questions below to provide your
assistance.

10. Which of the following would not be part of the problem that Amie and Cody need to
solve in order to begin designing their robot?

		Percentage	Responses
A. The robot must be able to travel in standing water.		**30.2**	**16 +3**
B. The robot must be able to avoid obstacles such as large rocks and existing trees.		34.0	18
C. The robot must be able to go to a specific location, using GPS.		26.4	14
D. The robot must be able to dig a hole.		9.4	5
		Total responses:	**53**

16) 11. As a part of the design process, Amie and Cody visit an engineering library to look at existing patents. Which step in the Engineering Design Process are they doing?

	Percentage	Responses
A. Identify the problem	21.2	11
B. Research the problem	**46.2**	**24 -5**
C. Select a solution	21.2	11
D. Construct a prototype	11.5	6
Total responses:		**52**

17) 12. Amie and Cody are reviewing the possible solutions to select one to test by building a prototype. Which of the solutions below do you think is most important to the project?

	Percentage	Responses
A. The robot should operate quietly to lessen the disturbance to wildlife in the area.	7.5	4
B. The robot should be on tracks to cover diverse terrains.	18.9	10
C. The robot should have a camera so the operators can see what it is doing from anywhere with an Internet connection.	37.7	20
D. The robot should have a robotic arm that can do tasks such as dig the hole, place the tree and replace the soil.	**35.8**	**19 -8**
Total responses:		**53**

18) 13. Which of the following strategies would be important to evaluating Amie and Cody's solution?

	Percentage	Responses
A. Testing the prototype by planting trees in different orchard settings or environments	25.5	13
B. Asking other engineers on your team to review their design and prototype	19.6	10
C. Check the design with specialized computer software to find potential flaws	17.6	9
D. All of the above	37.3	19 -4
	Total responses:	**51**

19) Technology – Robotic Programming
Use the obstacle course shown to answer the robot programming questions below. The dashed
line(s) shows the path of the robot. The solid line is a black electrical tape one inch wide.

14. Which sensor is most likely used to navigate the robot between points A and C?

	Percentage	Responses
A. Light	**28.3**	**15 +4**
B. Sound	24.5	13
C. Touch	20.8	11
D. Ultrasonic	26.4	14
	Total responses:	**53**

20) 15. Which of the marked points on the image above corresponds to the pseudocode shown here:
Loop 4 times – Forward one tire rotation, Turn ninety degrees right

	Percentage	Responses
A. Point B	34.0	18
B. Point D	**34.0**	**18 +3**
C. Point E	20.8	11
D. Point F	11.3	6
	Total responses:	**53**

21) 16. At point F, the robot spins counterclockwise for at least 1080 degrees. Which
pseudocode line would cause the robot to turn 1080 degree?

	Percentage	Responses
A. Forward, left motor 10 rotations	15.4	8
B. Forward, right motor 10 rotations	34.6	18
C. Forward turning to the left, left and right motors 10 rotations	**34.6**	**18 +2**
D. Forward turning to the right, left and right motors 10 rotations	15.4	8
Total responses:		**52**

22) 17. Which of the marked points in the image above corresponds to the pseudocode shown here: Wait until touch, reverse two wheel (720 degrees) rotations

	Percentage	Responses
A. B	25.0	13
B. D	23.1	12
C. E	**32.7**	**17 -1**
D. F	19.2	10
Total responses:		**52**

23) 18. Which of the sensors listed would most likely not be used to complete this challenge?

	Percentage	Responses
A. Light	3.8	2
B. Sound	**36.5**	**19 -2**
C. Touch	26.9	14
D. Rotation	32.7	17
Total responses:		**52**

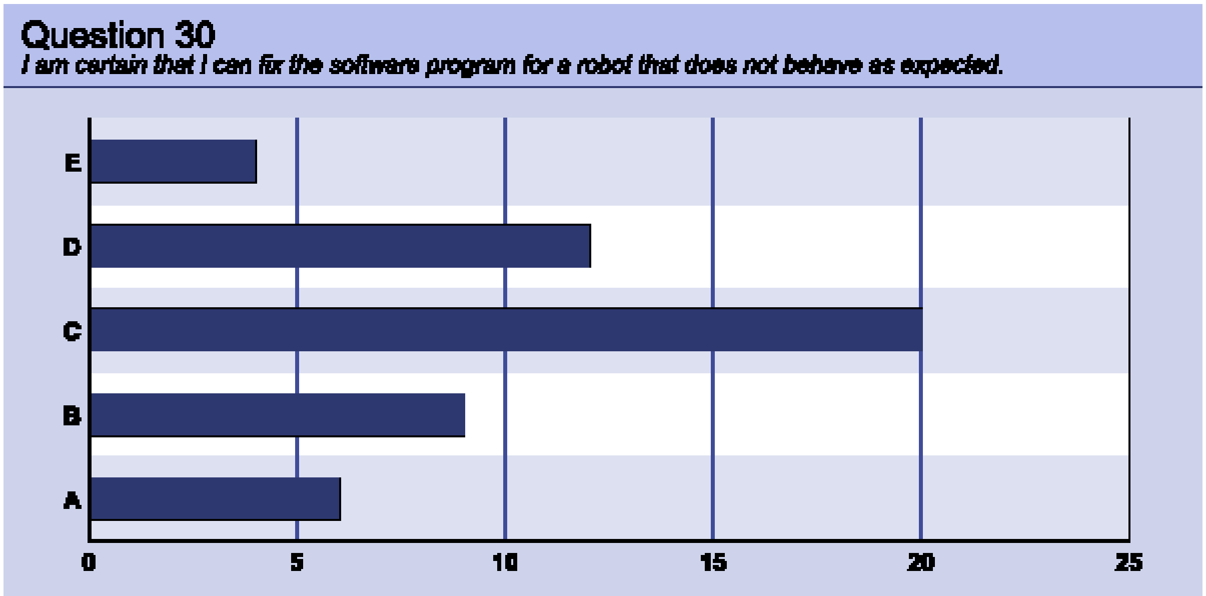
24) 19. Which pseudocode is the most reliable way to program the robot at point C (find the tower and then turn, using an ultrasonic sensor) in the image above?

	Percentage	Responses
A. Forward 2.3 wheel rotations to the tower	20.8	11
B. Forward 828 degrees to the tower	35.8	19
C. Forward 1.6 seconds to the tower	28.3	15
D. Forward until 15 inches from the tower	**15.1**	**8 -1**
	Total responses:	**53**

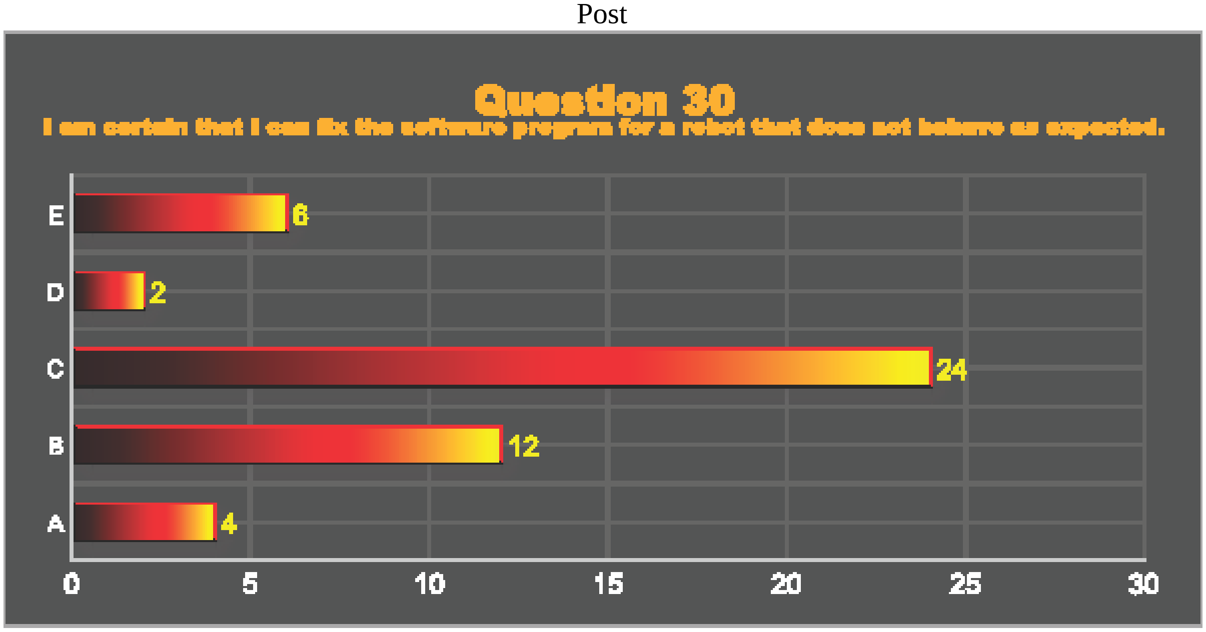
Appendix 6

Sampling of Pre and Post Interest Survey Questions

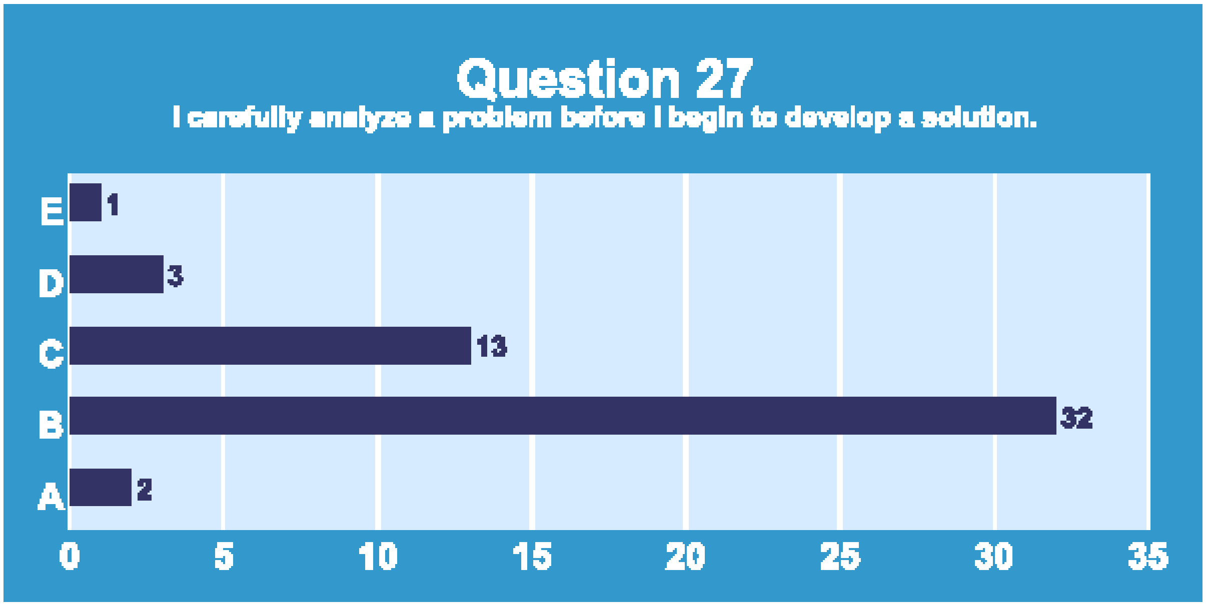
Pre



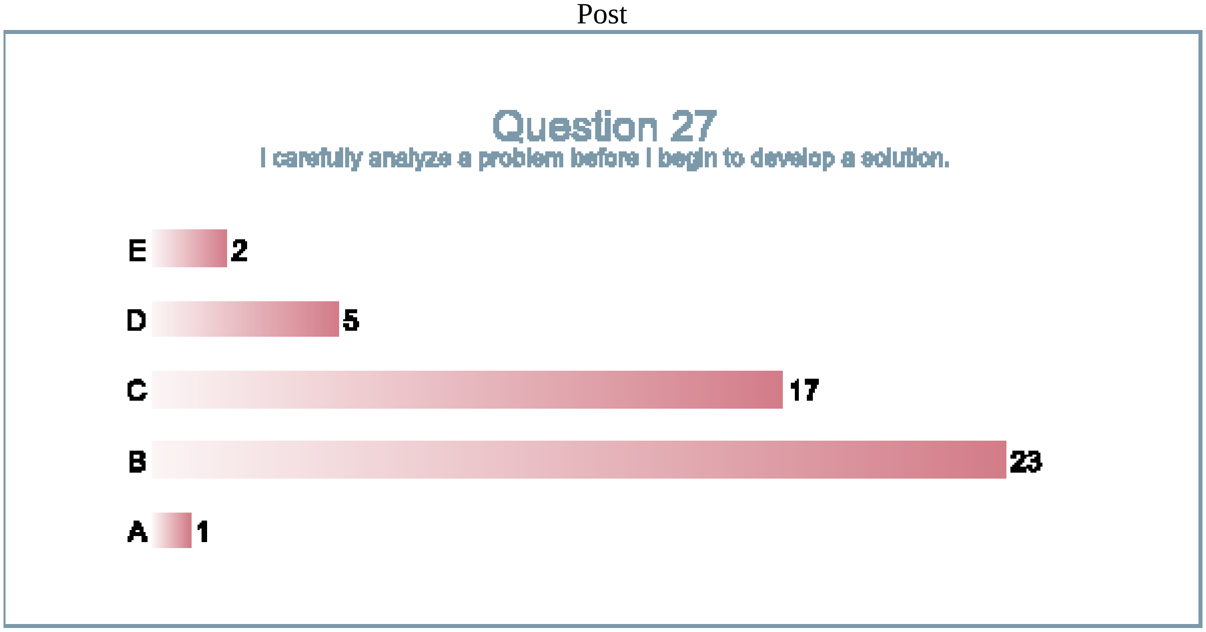
Post



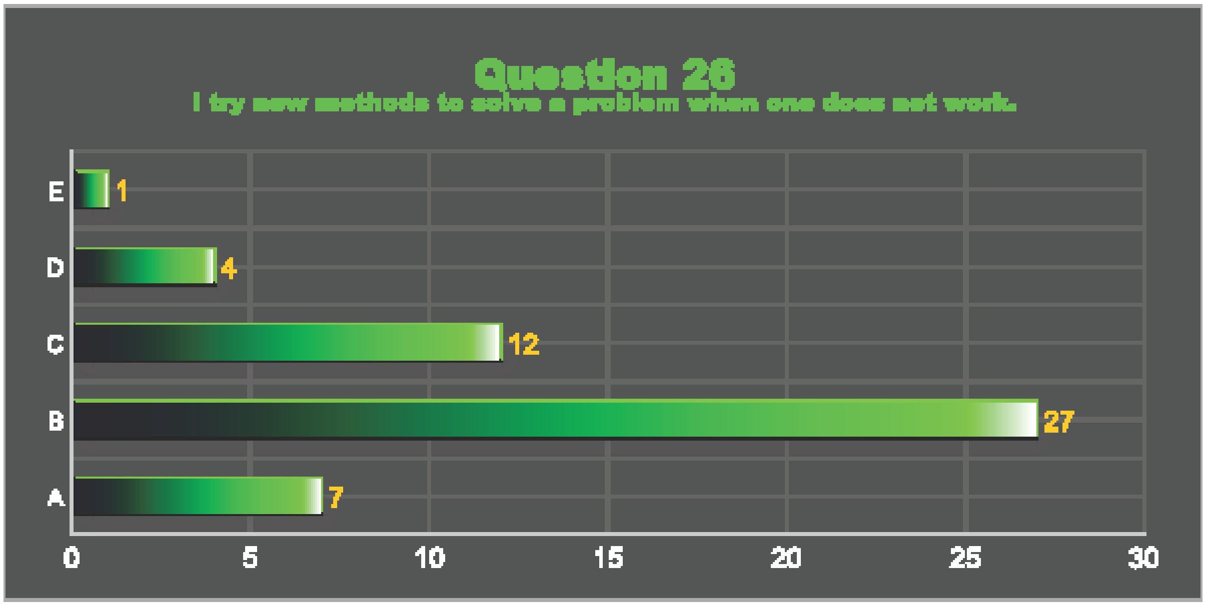
Pre


Question 27
I carefully analyze a problem before I begin to develop a solution.
E 1
D 3
C 13
B 32
A 2
0 5 10 15 20 25 30 35

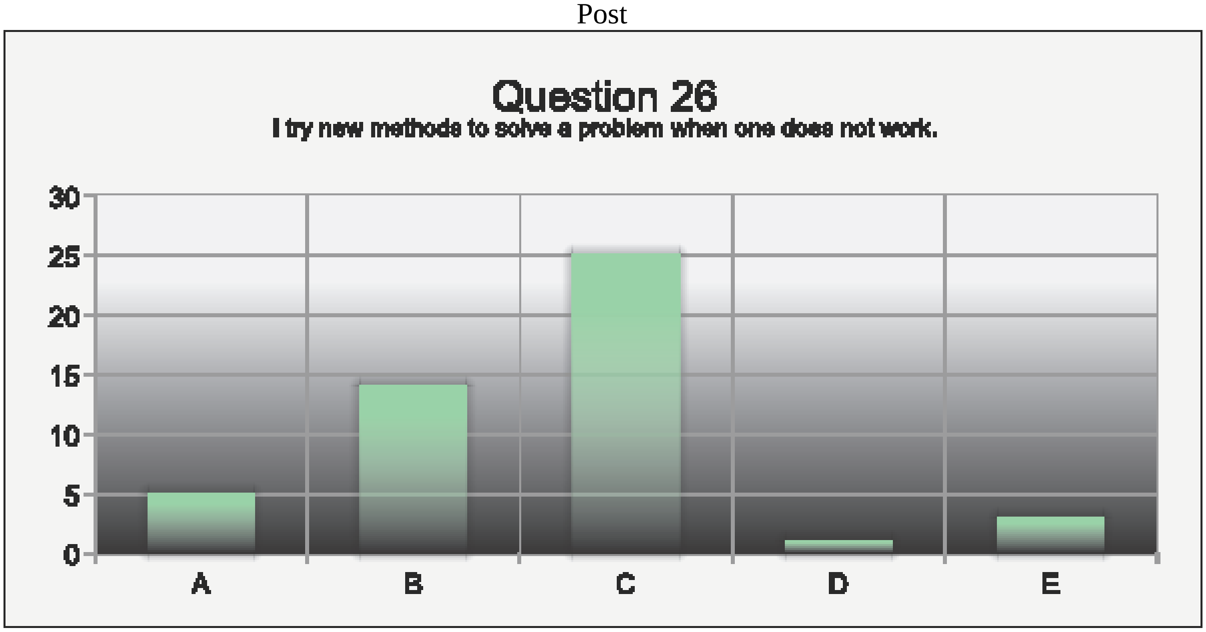
Post


Question 27
I carefully analyze a problem before I begin to develop a solution.
E 2
D 5
C 17
B 23
A 1

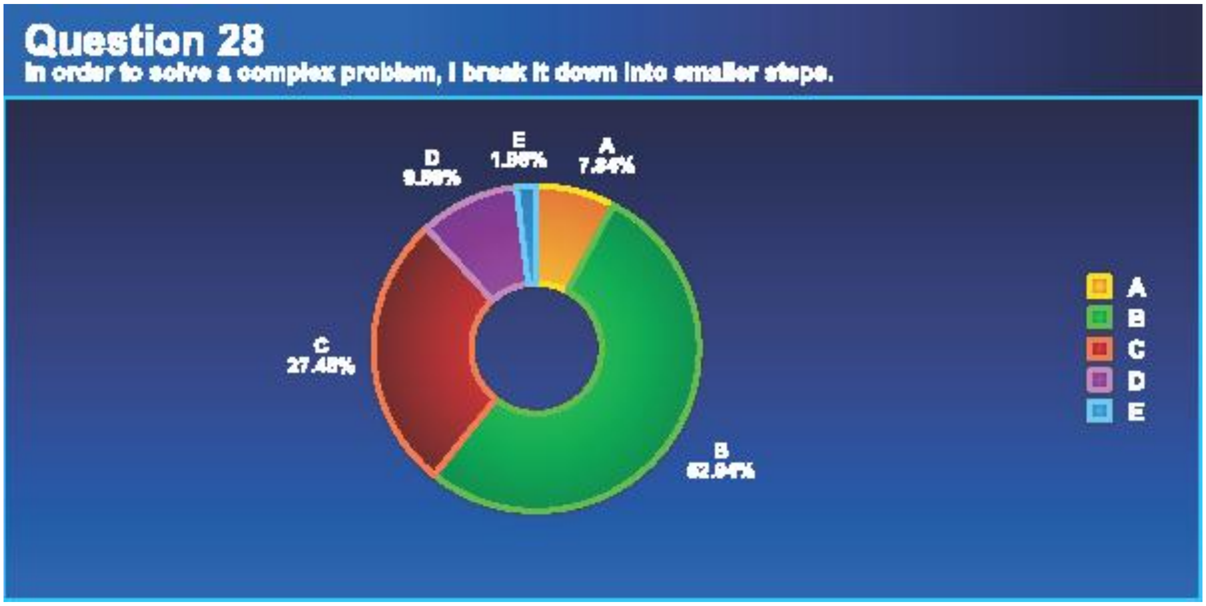
Pre


Question 26
I try new methods to solve a problem when one does not work.
E
D
C
B
A
1
4
12
27
7
0
5
10
15
20
25
30

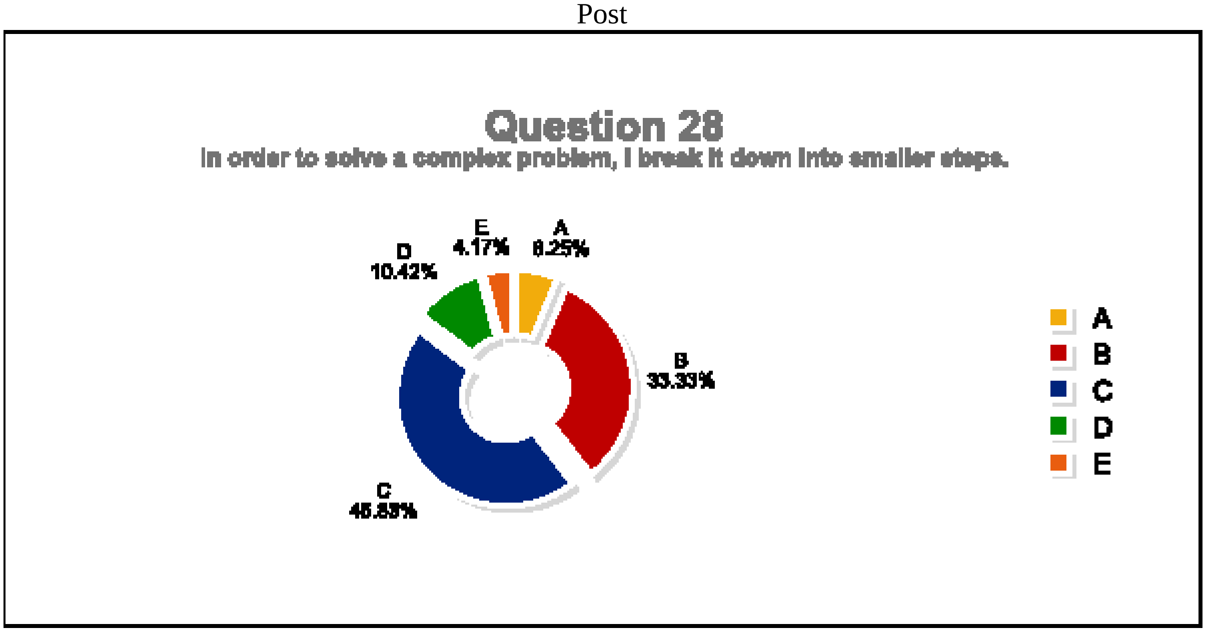
Post


Question 26
I try new methods to solve a problem when one does not work.
30
25
20
15
10
5
0
A
B
C
D
E

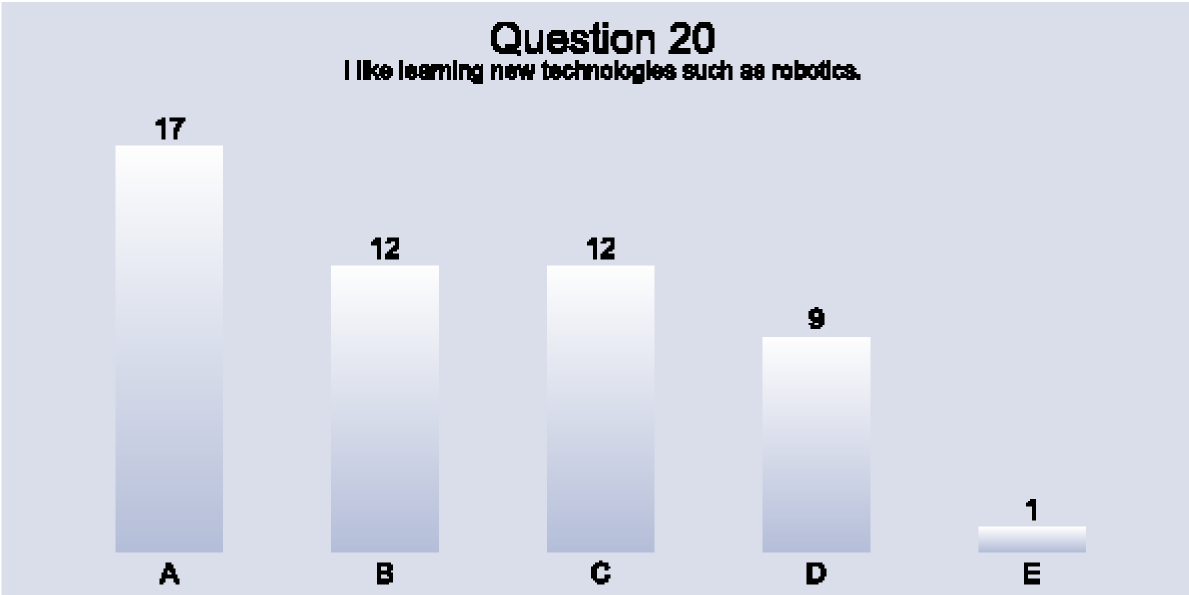
Pre


Question 28
In order to solve a complex problem, I break it down into smaller steps.
E
1.96%
A
7.84%
D
9.80%
C
27.45%
B
52.94%
A
B
C
D
E

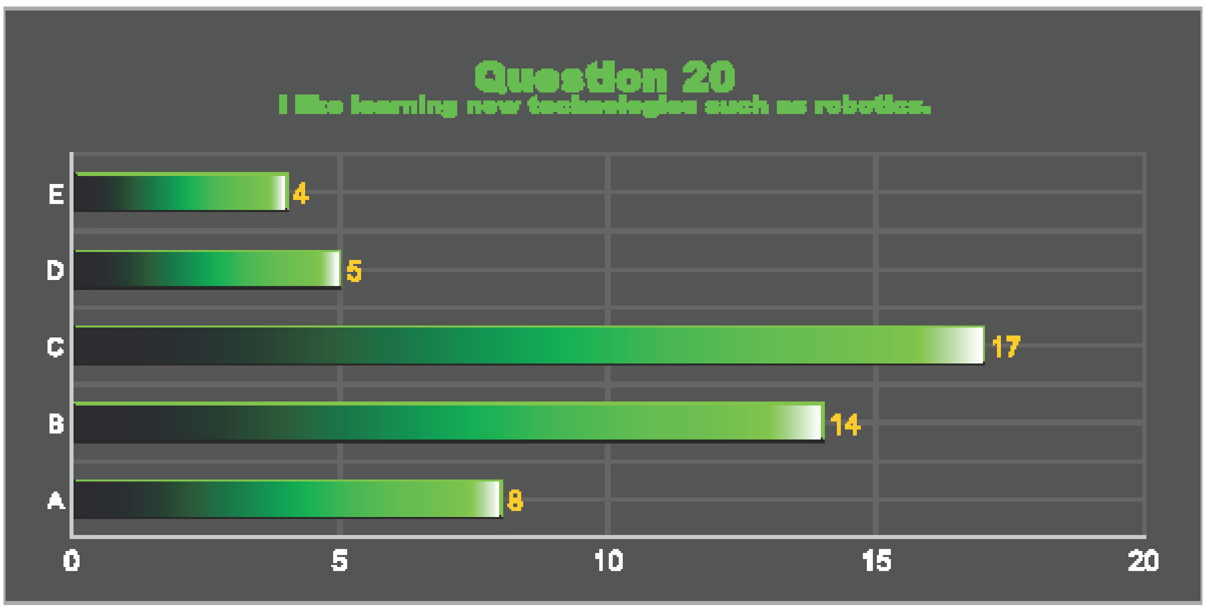
Post


Question 28
In order to solve a complex problem, I break it down into smaller steps.
E
4.17%
A
6.25%
D
10.42%
B
33.33%
C
45.83%
A
B
C
D
E

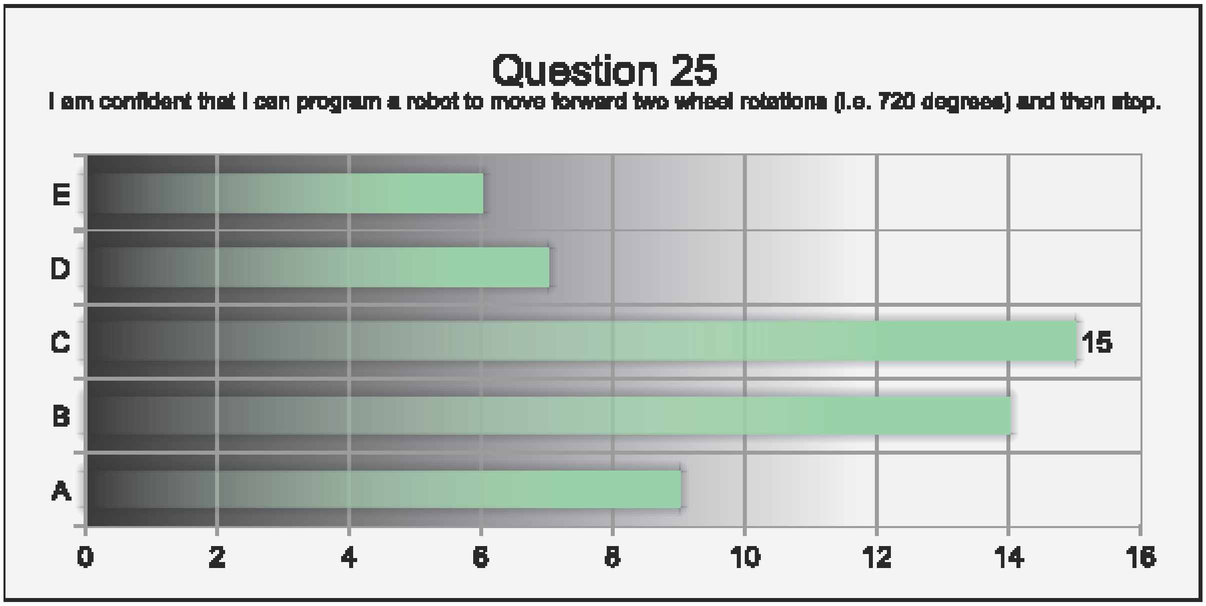
Pre


Question 20
I like learning new technologies such as robotics.
17
12
12
9
1
A
B
C
D
E

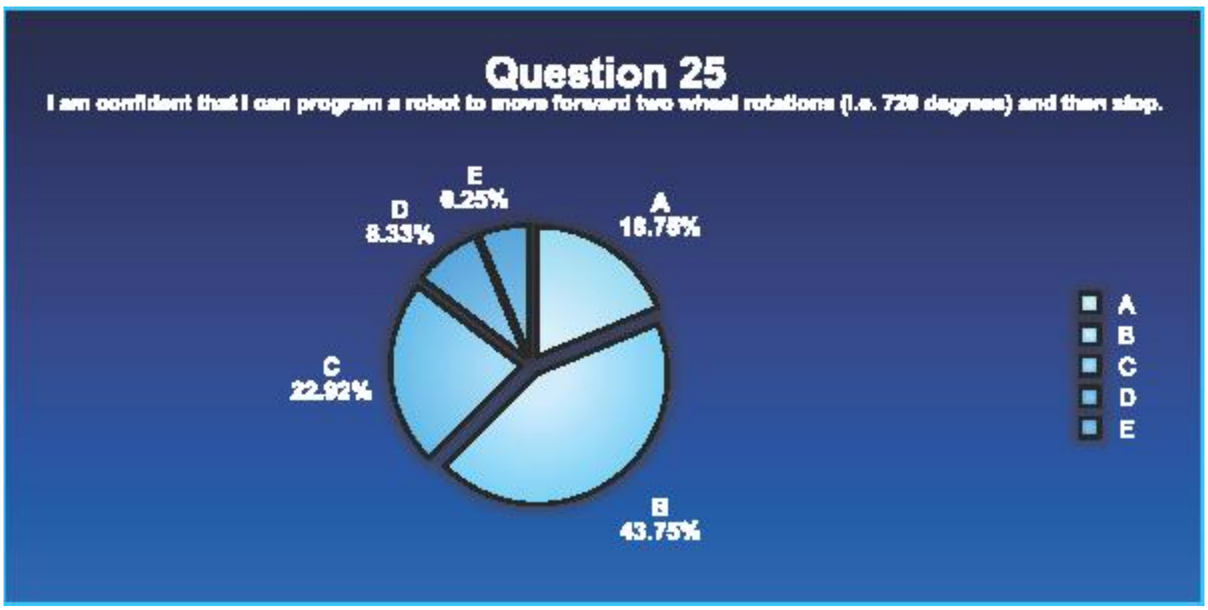
Post


Question 20
I like learning new technologies such as robotics.
E
D
C
B
A
4
5
17
14
8
0
5
10
15
20

Pre

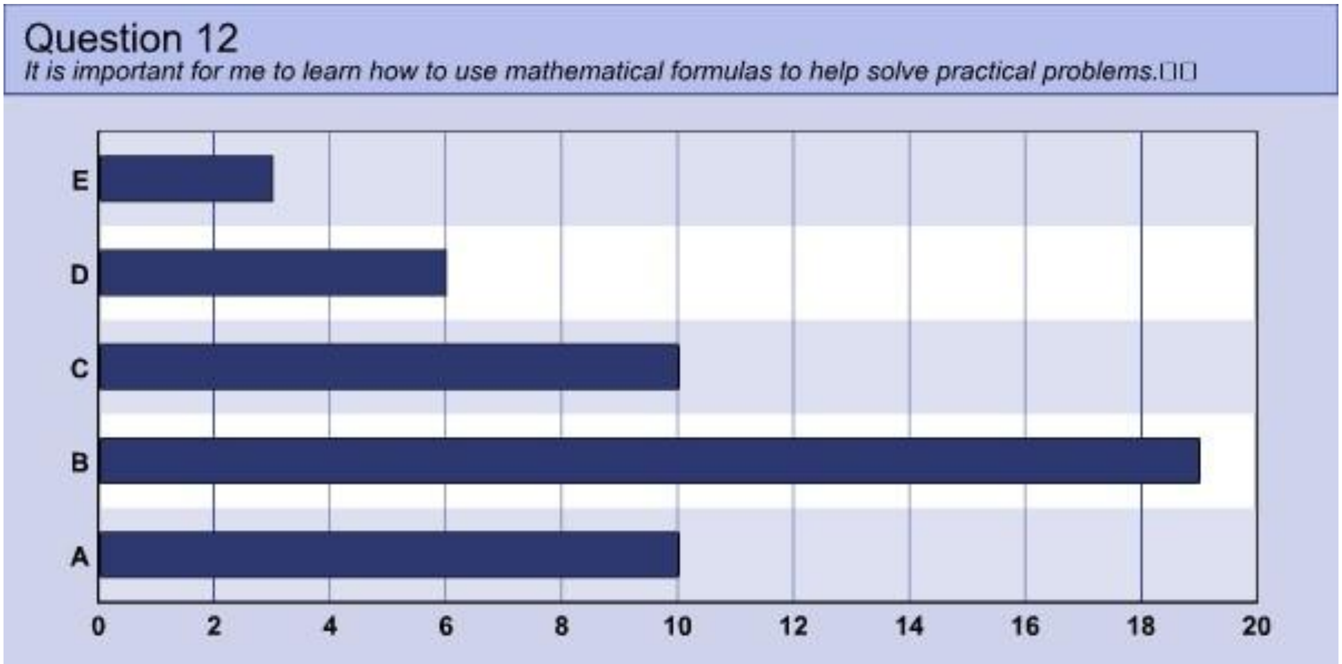

Question 25
I am confident that I can program a robot to move forward two wheel rotations (i.e. 720 degrees) and then stop.
E
D
C
B
A
15
0
2
4
6
8
10
12
14
16

Post

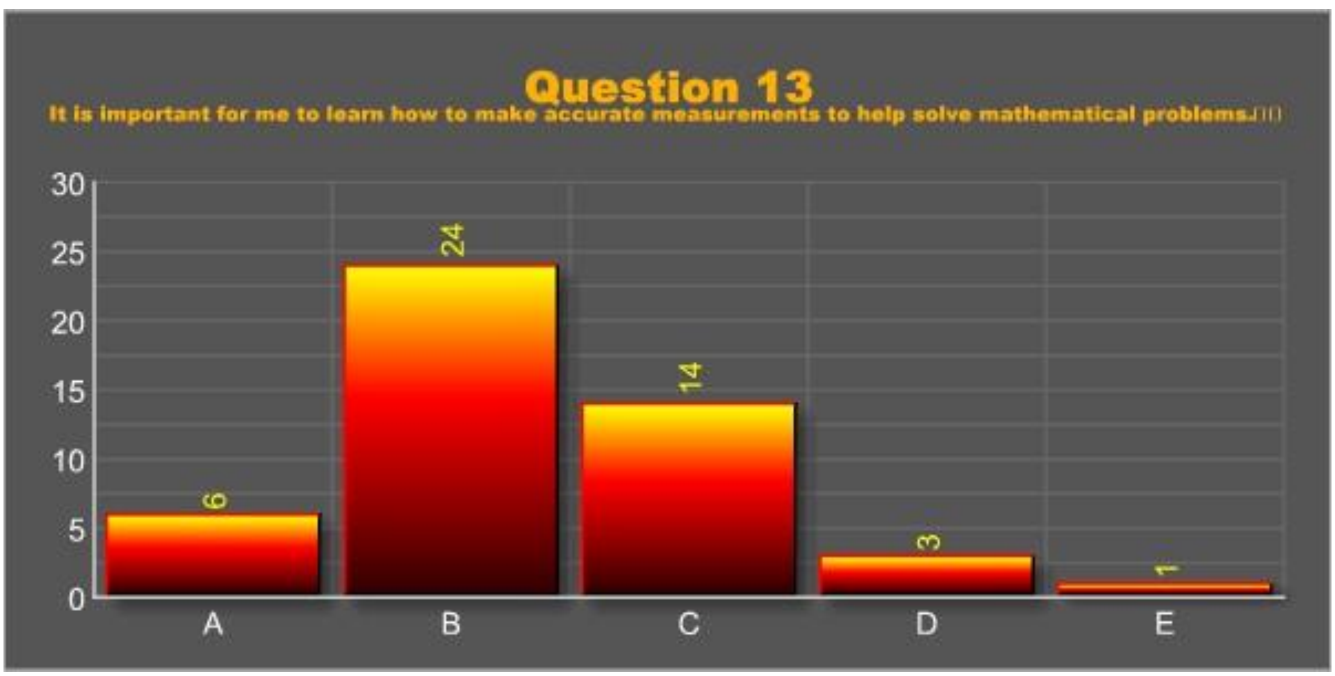

Question 25
I am confident that I can program a robot to move forward two wheel rotations (i.e. 720 degrees) and then stop.
E
6.25%
D
8.33%
A
18.75%
C
22.92%
B
43.75%
A
B
C
D
E

Appendix 7

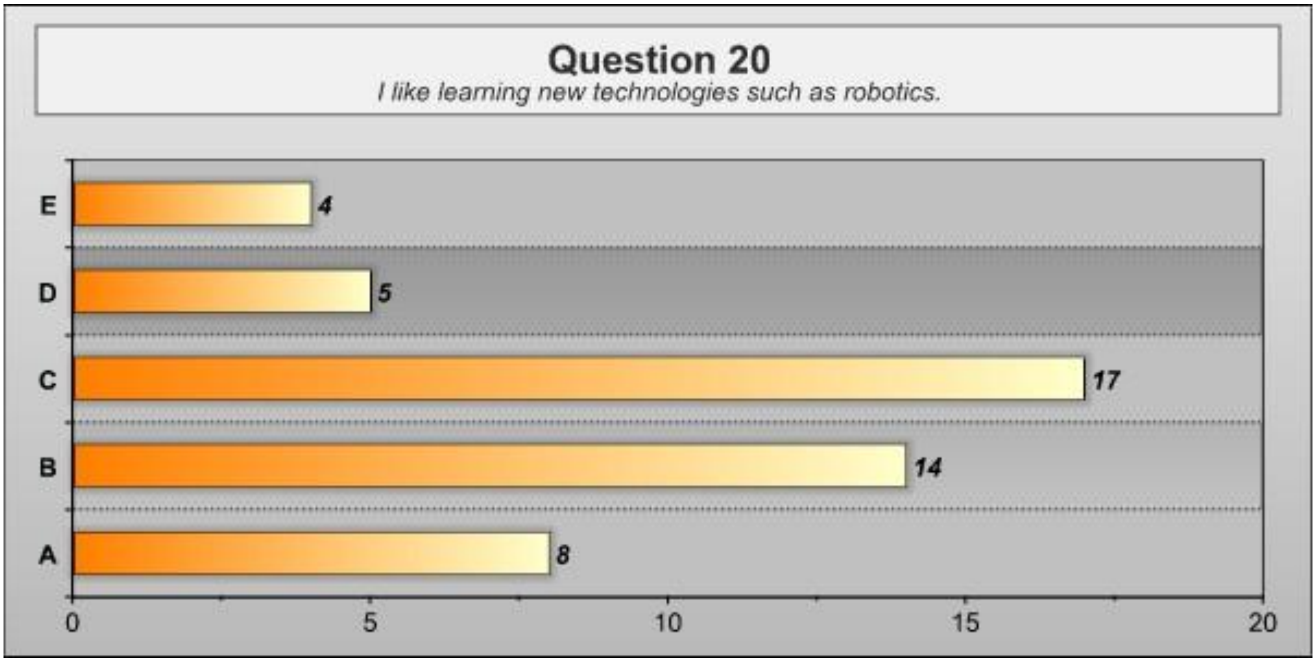
Student Survey Results



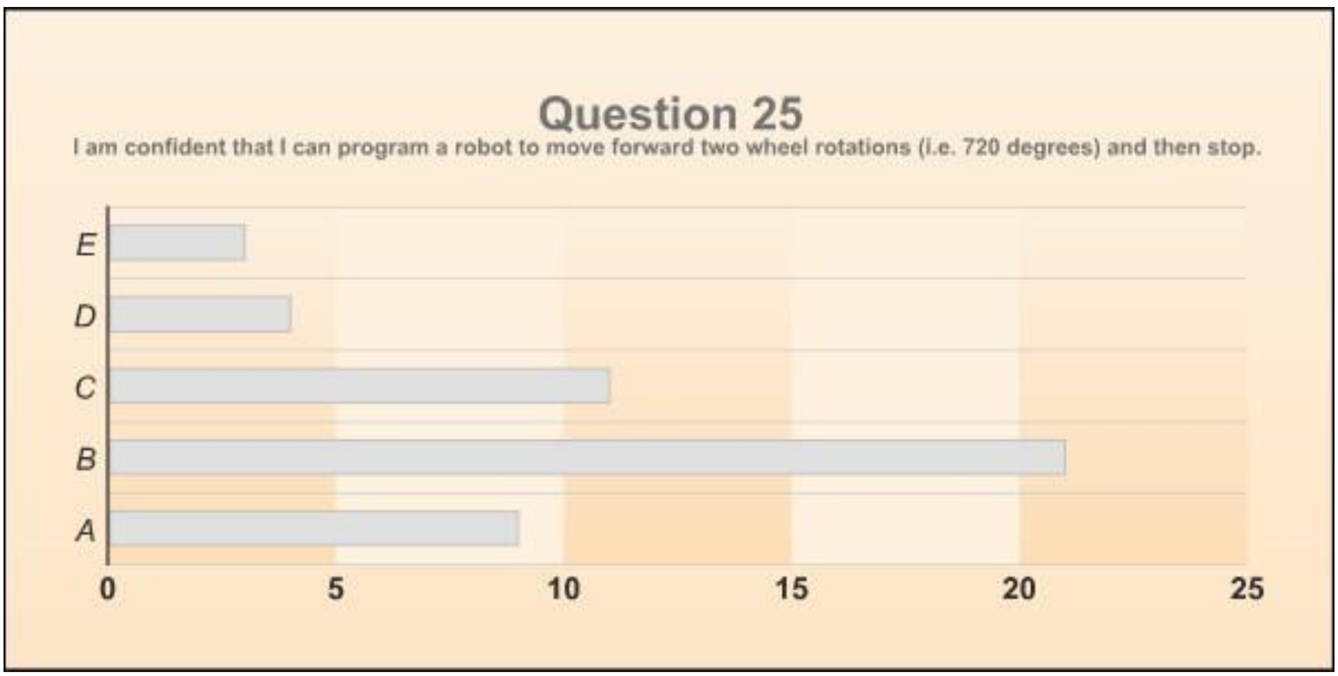
60 percent of students agree mathematical formulas are helpful in solving problems.



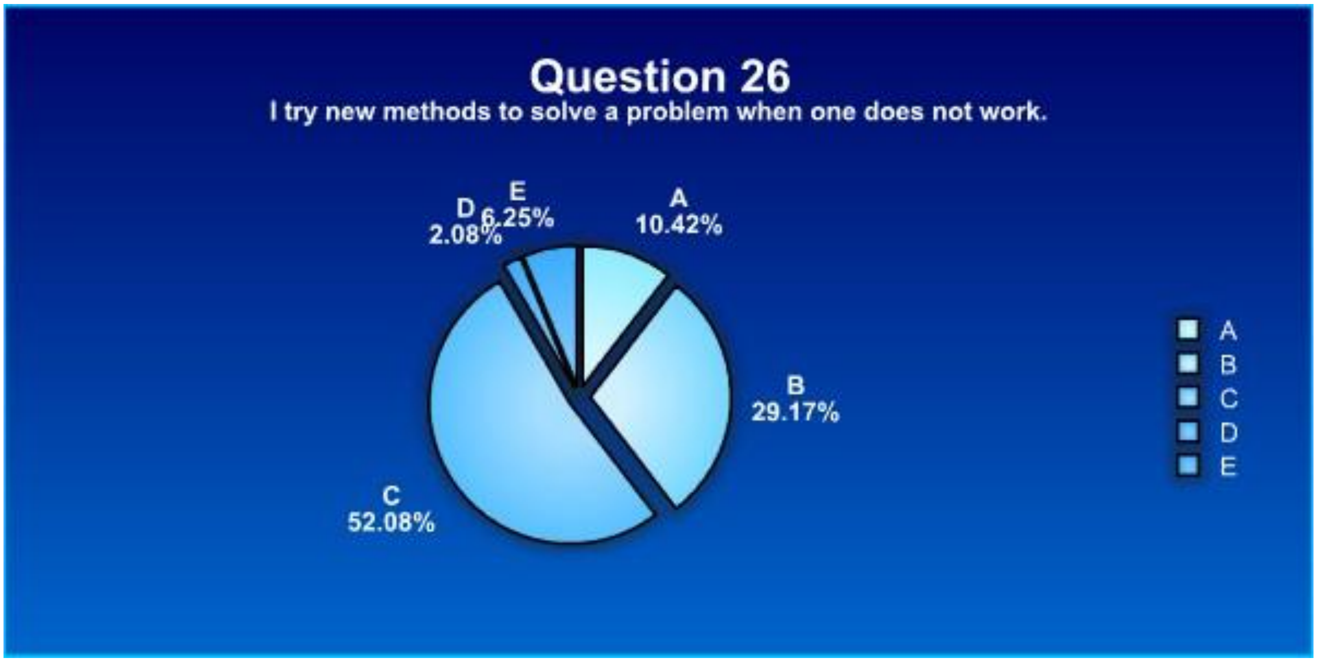
62% think it is important to use accurate measurements to help solve mathematical problems



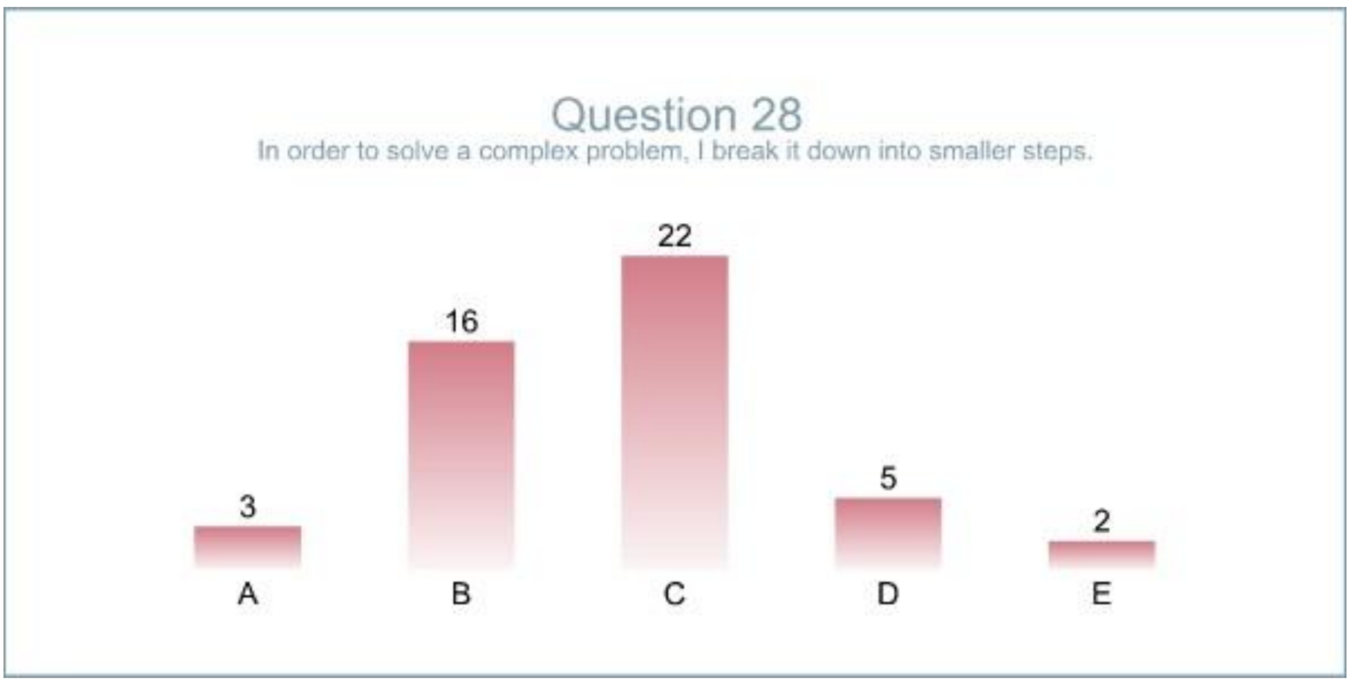
45 % of students liked learning about robots, while 35% were neutral about it.



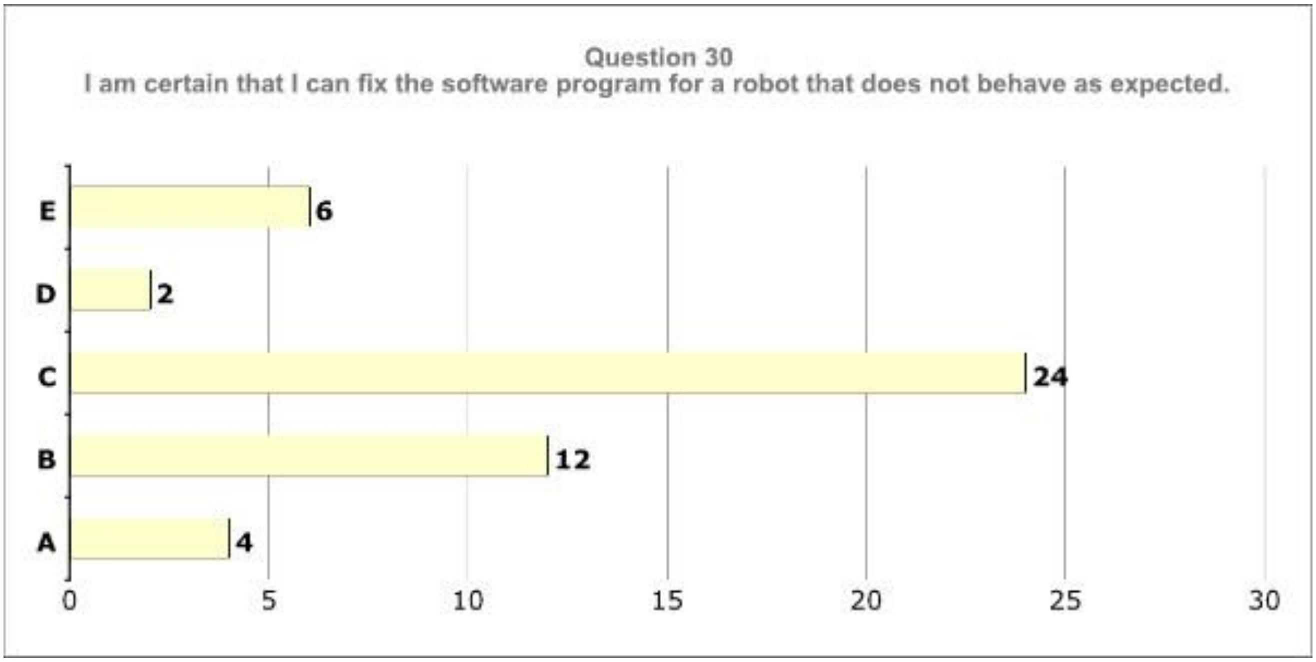
62.5 % were confident they could program the robot similar to the challenge in lesson one.



Only 39.6% of the students try new methods to solve a problem when one does not work.



Only 39.6 % break down a problem into smaller steps to solve a complex problem.



Only 33% felt they could fix a software problem when the robot did not behave as expected.

Appendix 8

Student Survey Feedback

For you personally, what was the best part of the lesson? Why?

Complete list of all responses given to this question

- playing with the puppy robot

- working with the robot

- working with the robots

- messing around with the robots but really i didnt really like the unit.

- the robot

- learning about robots because ive never seen one like the ones we used

- The best part of this project was that we got to see how the robot goes back and forth.

- watching the robot run

- watching the robot run fast becouse it was the most excting part

- Making the robots turn

- I liked programing the robot.

- makeing the robot move because it helped see far it wint

- i think that the bast part of the lesson was seeing the robots acctually do what you showed them to do.

- the best part of the lesson was when we got to see the robot do the actions that we programmed

- i think the best part of this lesson is seeing how the robot worked when the programing is set

- downloading the programms and seeing if they would work

- makeing the robot move because it helped you see how much u did

- seeing your robot do what you told it to do

- The best part was that we actully made the robot move which was very fun.

- the best part was seeing the robot move because i know that i was the one who did it

- the best part was watching the robots do what you told them to do

- being able to program a robot to do what i want it to

- I liked making the robot do different things because I like to expirement and try different things.

- The best part to me was when we got to test the programs because we got to see if our programs worked

- i think the fun part was when we prgramed the robot

- programing the robot to go forward

- Having the robot to go a certain distance and the come back.

- Calculating the rotations of distace because it was the easier thing to do

- making the robot move

- getting to make the robot a certain distance and back

- The best part was that we were able to see what we had done.

- full speed ahead because you made it go fast

- none of it it was to confusing

- I didnt have a favorite part of the lesson. I didnt like it.

- i honestly think that it wasnt that interesting to make the robots! because im not really that into robots!

For you personally, how could the overall lesson or activity be improved?

Complete list of all responses given to this question

- if we did it longer

- more activiys

- getting more time to work on the project

- BY maybe working more on the project

- slow it down

- add another day so we could do the robot challenge

- I think that the lesson should have been longer.

- I think the lesson could be improved by more time to program different things on the robot instead of just moving around so I mean like talking or jumping.

- letting us figure more stuff out kon uor own

- well they could make it alot more interesting for everyone and let the kids choose the partners they wanted and let the kids to more movements instead of

just straight lines and twisting

- Maybe have us do diffrent experiments and we teach the class what other things can be done by the robot.

- you could let us build the robots

- you could lets us build the robots

- if we got to actually make the robot instead of just programing the robot.

- by us making the robot on our own

- to try and learn more.

- more on how to program and the affects of it

- i would have liked a little more guidance in the project

by getting a better understanding

- i think that it could be improved by makind it easier and less math.

- More directions.

- i think the lesson could be improved by making less math in it

- trying to make the programing a little bit easyer then how it is because it is very confusing

- doing more videos to explane better

- like sometimes the things that they made us do were confusing so i didn't understand them.

- it could be better explained on wheels and distance because the videos were very confusing and i had no idea what i was doing

- having a little easyer dirrection on how to make the program

- I think it could be improved by making the "blank canvas" easier to understand.

- Help people so they can enjoy it like everyone else.

- have battles

- have races to see whos is beter

- i think it needs to be more fun! because i thought it was boring and i was nott interested!

- make it more interesting

- you could have done a better program to make fun

- It could be a little more fun by making the videos or robotics a little harder to do.

- making it go straiter

- by having the robot go faster

- **Nothing**

- **i dont really know**

- **at the end i felt smarter**

Anything else to tell me about this activity?

Complete list of all responses given to this question

- **it was fun**

- **it was fun**

- **It was really fun but went really fast**

- **It was fun to do.**

- **Fun**

- **A.W.E.S.O.W!!!!!**

- **It was interesting.**

- **it was fun to program them**

- **I just really liked when we made it move. I really liked that.**

- **the activity ws very exciting**

- **I liked when we seen the robot move**

- **That it was an o.k. activity for us to do.**

- **this activity was kind of fun but not much**

- **it was boring**

- **it was boring**

- **i thought it was boring**

- **it was fun ang kinda boring**

- **it shold be more fun, it was veryyyyyyyyy boring and dull and i was very disappointed**

- **i think we need to have some more fun and not watch all the videos. they got verrrrrryyyy boring**

- **i did not like eny of the robots**

- **i didnt like wheels and distance**

- **have races and have it go longer distances.**

- **It would be more interesting if you would have harder tricks like spinning or jumping**

- **it would of been funner if we could of just done what we wanted to on the robot**

- **no nnot really**

- **no**

- **nooooo**

- **No**

- **noi**

- **no**

- **nope**

- **no**

- **no!**

- **no**

- **no**

- **No**

- **nope**

- **no**

- **Nope**

- **no**

- **no**

- **No.**

- **no.**

- **no**