Evaluation Report of the Robotics & Engineering Design Curriculum

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Executive Summary

This report provides findings from the evaluation of the Race to the Top (RT3) funded Robotics and Engineering Design Curriculum (REDC). The Robotics and Engineering Design Curriculum (REDC) is a product developed under the collaboration of Race to the Top (RT3), the Georgia Department of Education, and Georgia Tech's Center for Education Integrating Science, Mathematics, and Computing (CEISMC). The REDC presents an alternative instructional philosophy that changes the traditional instructional environment used in Career, Technical and Agricultural Education (CTAE) classes to a project-based, integrative STEM environment. The term *integrative* describes an ongoing, dynamic, student-centered process of teaching and learning emphasized by this instructional design[1]. The REDC is aligned to the Georgia Performance Standards in 8th grade physical science, the 8th grade Common Core Georgia Performance Standards in mathematics, and the 8th grade Technology Systems Career Tech and Agricultural Education (CTAE) course. Through project work, students formulate questions, conduct research, collect data, and design and engineer solutions. The REDC utilizes engineering design, LEGO™ robotics, and 3-D prototyping and manufacturing to teach mechanics, and wave and energy concepts integrated with algebra and geometry. This internal evaluation was conducted by the Georgia Tech Center for Education Integrating Science, Mathematics, and Computing (CEISMC).

Georgia Tech CEISMC's Race to the Top REDC work began in April 2011 and ended in August 2014. The Race to the Top goal and action item related to the REDC states: **GOAL 3**: **Prepare more students for advanced study and careers in the sciences, technology, engineering, and mathematics, including by addressing the needs of underrepresented groups and of women and girls in STEM areas. ACTION (19):** Utilize Robotics/Engineering Design to teach middle level science courses. Building on an existing middle school Integrated STEM courses created in Cobb County and an NSF-sponsored 8th grade engineering design and robotics course being created at Georgia Tech, Georgia Tech will expand the use of engineering and robotics in middle schools, specifically within integrated STEM classrooms.

Methods

The outcome evaluation of the REDC course focused on the impacts upon participating students in two primary areas: (a) Student learning and (b) a number of non-cognitive measures including engagement, self-efficacy, and interest in STEM. All data presented in this report were collected during the 2013-2014 academic school year.

Student learning was measured through a pre/post-assessment administered to students at the beginning and end of each Unit during the 2013-2014 academic school year. The assessment captured content knowledge in mathematics, science, and engineering

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[1] Wells, J. (2013). Integrative STEM Education at Virginia Tech: Graduate preparation for tomorrow's leaders. *Technology & Engineering Teacher, 72*(5), 28-34.

standards that were addressed by REDC. In addition, one participating school provided the opportunity for a quasi-experiment to be implemented, specifically a non-equivalent groups design. In this school, a comparison group of students were participating in an engineering course occurring parallel to the REDC course. Students in this comparison course were also administered items of the pre-/post-assessment of content knowledge related to science and mathematics, which allowed an estimation of the contribution of the REDC curriculum in this school. Because REDC is designed to provide students with an applied context for specific science and mathematics content that is based in the 8th grade standards, test items were developed to measure the specific content areas that were addressed through the REDC Units. In addition to content knowledge gain, changes in non-cognitive skills related to STEM were examined through a pre/post-survey.

Key Findings

A clear understanding of the components to effectively implement REDC is necessary for the effectiveness of implementation.
School level administrators expressed support for REDC but in several instances, their actions created barriers for implementation. For example, scheduling proved to be a problem in many schools. Administrators in some schools would change the nine-week duration to a semester long course with little notification to teachers. Therefore, course planning became an issue. In some settings, students were placed in the course without any prior knowledge they would be there. Instructional time was also decreased in some schools to accommodate other courses or schedules.

Teachers should have a willingness to implement new strategies and be comfortable with the challenges that may occur. Teachers should be open to professional learning focusing on REDC course concepts including problem-based learning, the engineering design cycle, and use of innovative instructional technologies such as 3D printers and CAD (Computer-Assisted Design) software.
Some teachers were resistant to adapting their teaching styles. A particular issue was the planned collaboration between the CTAE teacher and the mathematics and science teachers. This collaboration occurred in only one school, which already had a commitment and school culture of collaboration.

Students showed modest increases in content knowledge as evidenced by pretest/posttest scores.
Improvements in content knowledge, though modest, were apparent in every school. Overall, the items of the content test that showed the greatest increases were related to interpreting slope of the line, with students showing a 16% increase in determining the slope of a line and a 10% increase in identifying a line with a positive slope.

Among the seven Non-Cognitive skills that were captured through the student survey, two were found to increase significantly while the remainder showed no significant change. The two constructs that showed significant change, both in the positive direction, were Science Self-Efficacy and STEM Self-Efficacy ($p < .05$). The constructs that did not show significant change were Math Interest, STEM self-efficacy, STEM Intent to Persist, Cognitive Engagement, and Psychological Engagement.

Programmatic Recommendations

1. Invest in sustained professional development and program support.

REDC promotes an innovative model of teaching and learning that focuses on project-based, integrative STEM learning. The term *integrative* describes an ongoing, dynamic, student-centered process of teaching and learning that encourages the connection of concepts from many different disciplines[2]. Therefore, CTAE teachers must have a deep understanding of mathematics and science content and how to integrate engineering and design into that content. They must also be able to collaborate with other teachers in a meaningful way. Data suggests this process is new to most CTAE teachers and requires sustained professional learning and support.

2. Develop a professional learning program for administrators.

Administrators indicated they wanted to implement the course as an integral part of STEM instruction. However, in some cases, it appeared that administrators wanted to list the REDC as a component of their STEM program but did not commit to it with proper scheduling and teacher support.

3. Develop Strong Partnerships with School Administrators

To address issues related to challenges of CTAE teacher collaboration with science and mathematics teachers, it is recommended that school administrators must have buy in to allow time for such collaborations in scheduling.

Conclusion

REDC is designed as a prerequisite to high school engineering career pathways. Many more schools and districts than could be supported through Race to the Top, are interested in REDC. However, additional funding, professional learning, and assistance will be required in order to successful implement the course.

[2] Wells, J. (2013). Integrative STEM Education at Virginia Tech: Graduate preparation for tomorrow's leaders. *Technology & Engineering Teacher, 72*(5), 28-34.

Background on Robotics and Engineering Curriculum (REDC)

Rationale for Developing the Curriculum

The Robotics and Engineering Design Curriculum (REDC) is a product developed under the collaboration of Race to the Top (RT3), the Georgia Department of Education, and Georgia Tech's Center for Education Integrating Science, Mathematics, and Computing (CEISMC). The purpose of the collaboration is to implement projects to increase student success in Science, Technology, Engineering and Mathematics (STEM). The REDC presents an alternative instructional philosophy that changes the traditional module instruction of a Career, Technical and Agricultural Education (CTAE) class to a project-based, integrative STEM environment. The term *integrative* describes an ongoing, dynamic, student-centered process of teaching and learning emphasized by this instructional design[3]. The REDC is aligned to the Georgia Performance Standards in 8th grade physical science, the 8th grade Common Core Georgia Performance Standards in mathematics and the 8th grade Technology Systems Career Tech and Agricultural Education (CTAE) course. Through project work, students formulate questions, conduct research, collect data, and design and engineer solutions. This unique learning environment is intended to increase interest and proficiency in STEM concepts.

The REDC seeks to develop and implement a rigorous eighth grade CTAE program that utilizes engineering design, LEGO™ robotics, and 3-D prototyping and manufacturing to teach mechanics, waves, electric circuits, and energy concepts integrated with algebra and geometry.

Schools Involved

One of the goals of the project was to provide access to underrepresented populations comprised of minority, low socio-economic status (SES), and female students in the Race to the Top partner school systems. The six schools were initially selected because they served these populations. In addition to the population characteristics, the schools were chosen based on administrative willingness to support an innovative learning environment. Finally, another criterion considered was the experience of the teachers implementing the curriculum. During the implementation phase we included teachers of varied experiences to see the related variety of implementation. Each of the schools is described below.

<u>Ben Hill County Middle School</u> is located in Ben Hill County School District and is designated as a rural fringe school by the National Center for Educational Statistics (NCES) that serves grades 6 through 8. During the 2012-2013 school year, it served a total of 802 students. The school offered the Technology Systems course prior to the implementation of the REDC. However, the school administration and teacher were interested in expanding the curriculum to include the type of project-based approach promoted in the REDC. The

[3] Wells, J. (2013). Integrative STEM Education at Virginia Tech: Graduate preparation for tomorrow's leaders. *Technology & Engineering Teacher, 72*(5), 28-34.

teacher was an experienced CTAE teacher. The demographics of the school are provided in the table below[4].

Table 1: Ben Hill County Middle School Demographic Information (n=802)

Race/Ethnicity	#	%	Gender	#	%
Asian/Pacific Islander	6	<1%	Male	416	52%
Black	335	42%	Female	386	48%
Hispanic	72	9%			
Multi-Racial	20	3%	Free/Reduced Lunch Eligibility	#	%
White	369	46%		650	81%
Native American/Alaskan Native	0	0%	CRCT 2012-2013 (8th grade)	#	%
			Science (Meets/Exceeds)	177	70%
			Math (Meets/Exceeds)	212	85%

Carver Road Middle School is located in Griffin-Spalding School District and is designated as a rural fringe school by NCES that serves grades 6 through 8. During the 2012-2013 school year, it served a total of 549 students. The administration in the school was interested in utilizing the REDC in the Technology Systems course. While an experienced CTAE teacher was in place at the beginning of the implementation of the REDC, the teacher retired at the end of the first year. The CEISMC REDC team leader helped select the new teacher. The demographics of the school are provided in the table below[5].

Table 2: Carver Road Middle School Demographic Information (n=549)

Race/Ethnicity	#	%	Gender	#	%
Asian/Pacific Islander	3	<1%	Male	261	48%
Black	281	51%	Female	288	52%
Hispanic	31	6%			
Multi-Racial	16	3%	Free/Reduced Lunch Eligibility	#	%
White	217	39%		417	76%
Native American/Alaskan Native	0	0%	CRCT 2012-2013 (8th grade)	#	%
			Science (Meets/Exceeds)	91	60%
			Math (Meets/Exceeds)	119	79%

[4] Governor's Office of Student Achievement (2014). *Report Card*. Retrieved from https://gosa.georgia.gov/report-card on September 9, 2014.
[5] Governor's Office of Student Achievement (2014). *Report Card*. Retrieved from https://gosa.georgia.gov/report-card on September 9, 2014.

Coretta Scott King Young Women's Academy Middle School (CSK) is located in the Atlanta Public Schools District and is designated as a city large school by NCES that serves grades 6 through 8. During the 2012-2013 school year, it served a total of 429 students. The administration and teacher were interested in implementing the REDC curriculum. The Technology Systems course had not been taught prior to the implementation of the REDC. The teacher was not an experienced CTAE teacher. The demographics of the school are provided in the table below[6].

Table 3: CSK School Demographic Information (n=429)

Race/Ethnicity	#	%	Gender	#	%
Asian/Pacific Islander	0	0%	Male	0	0%
Black	425	99%	Female	429	100%
Hispanic	1	<1%			
Multi-Racial	3	<1%	**Free/Reduced Lunch Eligibility**	**#**	**%**
White	0	0%		408	95%
Native American/Alaskan Native	0	0%	**CRCT 2012-2013 (8th grade)**	**#**	**%**
			Science (Meets/Exceeds)	61	52%
			Math (Meets/Exceeds)	86	75%

General Ray Davis Middle School (GRD) is locates in Rockdale County School District and is designated as a rural fringe school by NCES that serves grades 6 through 8. During the 2012-2013 school year, it served a total of 1001 students. The school offered the Technology Systems course prior to the implementation of the REDC. However, the school administration and teacher were interested in expanding the curriculum to include the type of project-based approach promoted in the REDC. The demographics of the school are provided in the table below[7].

[6] Governor's Office of Student Achievement (2014). *Report Card*. Retrieved from https://gosa.georgia.gov/report-card on September 9, 2014.
[7] Governor's Office of Student Achievement (2014). *Report Card*. Retrieved from https://gosa.georgia.gov/report-card on September 9, 2014.

Table 4: General Ray Davis Middle School Demographic Information (n=1001)

Race/Ethnicity	#	%	Gender	#	%
Asian/Pacific Islander	15	2%	Male	491	52%
Black	574	57%	Female	510	48%
Hispanic	48	5%			
Multi-Racial	40	4%	**Free/Reduced Lunch Eligibility**	**#**	**%**
White	324	33%		490	49%
Native American/Alaskan Native	0	0%	**CRCT 2012-2013 (8th grade)**	**#**	**%**
			Science (Meets/Exceeds)	258	87%
			Math (Meets/Exceeds)	284	97%

<u>Lilburn Middle School</u> is located in Gwinnett County School District and is designated as a suburb large school by NCES that serves grades 6 through 8. During the 2012-2013 school year, it served a total of 1799 students. The school offered the Technology Systems course prior to the implementation of the REDC. However, the school administration and teacher were interested in expanding the curriculum to include the type of project-based approach promoted in the REDC. The demographics of the school are provided in the table below[8].

Table 5: Lilburn Middle School Demographic Information (n=1799)

Race/Ethnicity	#	%	Gender	#	%
Asian/Pacific Islander	150	9%	Male	901	50%
Black	488	25%	Female	898	50%
Hispanic	1069	61%			
Multi-Racial	25	2%	**Free/Reduced Lunch Eligibility**	**#**	**%**
White	64	4%		1691	94%
Native American/Alaskan Native	3	<1%	**CRCT 2012-2013 (8th grade)**	**#**	**%**
			Science (Meets/Exceeds)	321	72%
			Math (Meets/Exceeds)	408	96%

<u>Woodstock Middle School</u> is located in Cherokee County School District and is designated as a suburb large by NCES that serves grades 6 through 8. During the 2012-2013 school year, it served a total of 1203 students. District level and building level administration and the experienced CTAE teacher were interested in implementing the REDC. REDC supported the district goal of implementing a curriculum that integrated 3D prototyping

[8] Governor's Office of Student Achievement (2014). *Report Card*. Retrieved from https://gosa.georgia.gov/report-card on September 9, 2014.

and manufacturing concepts into the CTAE program at the middle school level. The demographics of the school are provided in the table below[9].

Table 6: Woodstock Middle School Demographic Information (n=1203)

Race/Ethnicity	#	%	Gender	#	%
Asian/Pacific Islander	34	3%	Male	612	51%
Black	175	14%	Female	591	49%
Hispanic	221	19%			
Multi-Racial	56	5%	Free/Reduced Lunch Eligibility	#	%
White	712	59%		493	41%
Native American/Alaskan Native	5	<1%	CRCT 2012-2013 (8th grade)	#	%
			Science (Meets/Exceeds)	298	85%
			Math (Meets/Exceeds)	328	96%

Development of the course

The REDC is structured into four independent 9-week units, each of which can be taught as the stand-alone Engineering and Technology exploratory elective. The units are (1) Biomechanics, (2) Electromagnetic Radiation (EMR), (3) Renewable Energy, and (4) Analog to Digital Conversion. In each unit, students take the role of employees of an engineering company, responding to a "Request For Proposal "(RFP) by using LEGO® MINDSTORMS NXT robotics and 3-D prototyping to solve the relevant engineering challenge[10].

Each design challenge is presented to the students as a Request for Proposal (RFP). The whole class represents the company responding to the RFP. The students are part of development groups inside the company that propose solutions to the challenge to the whole company. The company decides on the appropriate solution using a design rubric. The Biomechanics Unit is described briefly below to provide an example. The RFP for the Biomechanics unit focuses on the locomotion of insects and how the understanding of the locomotion can be used to motivate innovation in the context of foot design. The unit is designed into six investigations. The investigations vary in length from three to eight days depending on the amount of material and the length of the school's class period.

Investigation 1: Each unit begins with a mini unit that prepares the students for the basic structure of the unit. As an example, the Balloon Babble investigation gives an overview of the universal systems model and the engineering design process. Here students are

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[9] Governor's Office of Student Achievement (2014). *Report Card*. Retrieved from https://gosa.georgia.gov/report-card on September 9, 2014.

[10] The curriculum can be viewed here: https://www.dropbox.com/sh/bxndrz0fbjhyxnh/AADrWkWxGq7Nkns2aY2ljTLDa?n=31551132

introduced to the concept of a "Request for Proposal" (RFP). The RFP asks the students to determine which of three devices enables the students to inflate the greatest quantity of balloons in the least amount of time. Students experiment with the three devices to acclimate themselves to the system used to inflate the balloons, and each group is assigned one of the devices to test. The students then conduct experiments to determine the efficiency of their device. Students are instructed on record keeping and journaling using an engineering notebook. They make decisions based on the data collected and present their results to the company (i.e. the whole class). The class decides which device best meets the criteria set forth in the RFP and formulates a response. The process is a short version of the rest of the unit and is used to prepare the students for the types of experiences they will have during the unit.

In *Investigation 2* of the Biomechanics unit, for example, they begin with the essential question: *What is locomotion and how do systems interact to allow locomotion?* During the course of the unit, students redesign an existing robot to increase its stability and efficiency as it traverses varied terrains. Students in groups read the RFP and identify and record the criteria and constraints in their engineering notebooks. After a guided discussion about the criteria and constraints, the student groups begin familiarizing themselves with the system, conducting experiments to determine the optimal gait for the robot. Student use the calculation of velocity to describe the motion of the robot. In groups they engage in guided discussions to help them understand differences in locomotion, and specifically locomotion strategies using legs. Students gain a further understanding of locomotion by watching a video of bug locomotion, which serves to motivate discussion, thinking and innovation.

During Biomechanics *Investigation 3*, students gain a first-hand experiential understanding of locomotion and friction by conducting an experiment in which they walk and drag their feet over three different surfaces. This investigation introduces the science concepts of force, friction, and energy. Then students extend their experimentation to the robotic model, traversing the three different terrains at different speeds. As students experiment with the robots, they begin to focus their attention on the interaction of the robot's feet and the surface.

In *Investigation 4*, students begin gaining technological knowledge by learning how to use the LEGO NXT light sensors and data logging tools. When they have mastered the use of the data-logging feature, students use the tool to gather data related to the locomotion of their robot over different surfaces. Students record data taken using the light sensor to determine friction and moments of slippage. Students are able to calculate velocity and use this information to determine the efficiency of locomotion.

In *Investigation 5*, students begin to redesign their robot to increase its locomotive efficiency. With the focus solely on redesigning the foot of their robot, the students begin working with SolidWorks, a 3-D graphical tool. They are guided on how to use the tool to produce foot designs that they will then use to prototype the feet using 3-D Printing.

During *Investigation 6*, the students iterate on the prototype based on testing data. The students are encouraged to complete at least three iterations. With the last iteration done, students in their groups formulate a presentation in *Investigation 7*, explaining the reasons why their design met the requirements of the RFP. After each student group presents their solution, the class decides on the solution that best meets the criteria. After the selection is made, each student drafts a formal response to the RFP, highlighting the design chosen.

The Electromagnetic Radiation, Renewable Energy, and Analog to Digital Conversion units follow the same basic progression. The challenge is introduced using an RFP, students are introduced to the system involved, they perform activities to familiarize themselves with the system, and they then engage in research to aid in formulating their solution. Students design a prototype, and subsequently test and iteratively improve the design until they find a solution that best satisfies the criteria and constraints of the RFP. Student groups then present their solution to the company (whole class). The company selects one of the solutions based on the criteria and constraints of the RFP and formulates a response to the RFP.

Implementation of the course

The project plan called for piloting of the curriculum before full implementation of the REDC. The curriculum developers piloted several weeks of the Biomechanics Unit in the schools during Year 1. During Year 2 of the project, the teachers in GRD, Lilburn, CSK, and Carver Road piloted the full units[11]. Woodstock and Ben Hill were added to these initial four schools during Year 3, which was the year of full implementation.

The pilot stage guided the iterative development of the curriculum and helped inform the activities for the first year's Summer Institute. The pilot phase informed the developers of areas for revision and update. Certain activities were updated to provide structure and scaffolding, especially regarding the integrative science and mathematics concepts. The pilot phase also afforded an opportunity to develop relationships that allowed free communication between the developers and the teachers. These lines of communication lead to the continuous feedback provided from the teachers to make real-time adjustments to the REDC. During this phase the first cohort of teachers were depended upon, not just for implementation, but for development as well.

During the summer before the implementation of the first cohort, the teachers for the four schools attended a Summer Institute to train on the units of the REDC. The Summer Institute provided hands-on experience on using the instructional technology for the course. Teachers were trained on using 3-D CAD design software and 3-D prototyping printers. Problem-based instruction was new to the first year cohorts, so time was allocated to train them on the best practices and strategies used to implement the curriculum and construct a learning environment that best integrates the STEM concepts taught in each unit.

[11] It should be noted that staffing issues at Carver resulted in the pilot occurring during only the first 45-day grading period. Carver participated during the second semester of the implementation year.

After the Summer Institute, the project plan called for visits to each of the schools to provide support and professional development. The number of visits was determined by the need of the instructor and the discretion of the developers. Initial visits were made to deliver the instructional materials and assist with set up for each of the schools. During these visits, a concerted effort was made to foster collaboration and teamwork with the teacher and school administration. During each 45-day grading period a minimum of 1 day of professional development was scheduled to assist the teacher in preparation for instruction of the REDC. Visits above the minimum were deemed necessary through communication with the teacher or by the developers.

It was common during the first 45-day grading period for the course developers to visit the schools on a weekly basis. The developers provided various support. For example, classroom resources were managed and maintained. Teachers were given additional professional development on the operation of resources, such as the 3-D printer and SolidWorks graphic design software. Developers taught lessons to model best practice of instruction for the teachers. School visits also provided a presence to the school administrators, teacher, and students, providing evidence of the commitment of the developers to the success of the course. As always, feedback was obtained during these visits that helped the iterative design of the course.

After the pilot year with the first cohort, a second Summer Institute was held for the four teachers from the first cohort along with the teachers from the two new schools. The Summer Institute provided a space for the first cohort to discuss strategies that worked and did not work. The feedback from this conversation continued to inform the iterative development of the curriculum into the final version. The instructors from the first cohort also participated as instructors of the Summer Institute.

For the second year of implementation, the first cohort was supported with a visit prior to the beginning of the school year for resource management and instructional technology support. For each of the 45-day grading periods, each of the first cohort schools were visited at a minimum 1 day to provide professional development and support. Among the first cohort schools, visits were made by request to solve issues with computers and/or 3-D printers primarily. During these visits, support was given for areas or activities that were revised due to feedback received or improvements made at the discretion of the developers.

The implementation for the second cohort resembled the implementation for the first cohort during the pilot year, though at a lesser frequency. Initial visits were made to deliver instructional materials and for set up. Follow-up visits included additional professional development with the printer and software, and modeling best practice of instruction. During these visits, a concerted effort was made to foster collaboration and teamwork with the teacher and school administration.

It should be noted that, due to constraints that were placed on the teacher at one school, which was a 30-minute instructional period, the course developers created a shorter version of the curriculum for the teacher to implement. Once the abbreviated version was created, the teacher was able to implement with little support due to the teacher's extensive experience with the instructional technology used.

A third Summer Institute was held after the second year of implementation and was open to all teachers in the state of Georgia who were interested in the REDC. Districts and schools were informed of the material requirements and were trained on the best practices and instructional strategies needed to teach the curriculum.

Methods

The outcome evaluation of the REDC course focused on the impacts upon participating students in two primary areas: (a) Student learning and (b) a number of non-cognitive measures including engagement, self-efficacy, and interest in STEM. All data presented in this report were collected during the 2013-2014 academic school year.

Student learning was measured through a pre/post-assessment administered to students at the beginning and end of each unit during the 2013-2014 academic school year. The assessment captured content knowledge in mathematics, science, and engineering standards that were addressed by REDC. In addition, one participating school provided the opportunity for a quasi-experiment to be implemented, specifically a non-equivalent groups design. In this school, a comparison group of students were participating in an engineering course occurring parallel to the REDC course. Students in this comparison course were also administered the pre-/post-assessment of content knowledge related to science and mathematics, which allowed an estimation of the contribution of the REDC curriculum in this school. The non-cognitive skills were measured through a pre/post-survey administered at the beginning and end of each Unit.

Because REDC is designed to provide students with an applied context for specific science and mathematics content that is based in the 8^{th} grade standards, test items were developed to measure the specific content areas that were addressed through the REDC Units. Items were adapted from those available through AAAS[12], and were also created by members of the CEISMC course development team. The pretest and posttest included the same items at both pretest and posttest administrations. Items were tested with students during Quarter 4 of the 2012-2013 academic year to determine validity and to adjust response options and language if deemed necessary. Pre/post tests are located in the Appendix.

In addition to content knowledge gain, changes in non-cognitive skills related to STEM were examined through a pre/post-survey. All items on the survey were on 4-point Likert-type rating scales ranging from Strongly Agree (=4) to Strongly Disagree (=1). The specific areas that were examined are enumerated below. Based on the pre-survey scores, the survey showed high internal consistency (Cronbach's $\alpha = 0.96$). The student survey in located in the Appendix.

[12] American Association of the Advancement of Science

1. Math Interest[13] (e.g., "Math relates to my life")
2. Science Interest[14] (e.g., "I enjoy learning science")
3. Science Self Efficacy (e.g., "I am confident I will do well on science labs and projects")
4. STEM Self-Efficacy[15] (e.g., "I can learn new ideas quickly in math class.")
5. STEM Intent to Persist[16] (e.g., "I intend to enter a career that will use technology.")
6. Cognitive Engagement[17] (e.g., "If I can't understand my schoolwork, I keep trying until I do").
7. Psychological Engagement[18] (e.g., "I am interested in the work in technology class")

Both the survey and the assessment were administered through an internet-based service (SurveyMonkey). For the assessments, students were also given hard copies in order to allow them to make notes and work out problems, although final responses were submitted online.

In an effort to provide context for the impact of the curriculum, aspects of the learning environment were captured. These contextual variables included: Publicly available school data, such as school demographic information, previous school academic performance, and urbanicity; as well as information reported by the teachers who were implementing REDC, including: level of implementation of the curriculum, collaboration with science and math teachers in the schools, and other school-related activities that might have had an impact on student outcomes.

Enrollment and Participation

Across the school year, a total of 779[19] students participated in REDC. The school schedules resulted in Schools 1, 2, and 3[20] having one class per quarter/semester; whereas

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[13] Adapted from *Math Anxiety Scale- Revised*: Haiyan, B, Wang, L., Wei, P., & Frey, M. (2009). Measuring mathematics anxiety: Psychometric analysis of a bidimensional affective scale. *Journal of Instructional Psychology, 36*(3), 185-193.

[14] Adapted from *Science Motivation Questionnaire*: Glynn, D. & Koballa, T. R. Jr., (2006). Motivation to learn in college science. In J.J. Mintzes & W.H. Leonard (Eds.) *Handbook of college science teaching* (pp. 25-32). Arlington, VA: National Science Teachers Assocation Press.

[15] Adapted from *Is Science Me?*: Weinburgh, M.H., & Steele, D. (2000). The Modified Attitudes toward Science Inventory: Developing an instrument to be used with fifth grade urban students. *Journal of Women and Minorities in Science and Engineering, 6*(1), 87-94.

[16] Adapted from *Middle School Self-Efficacy Scale*: Fouad, N. A., Smith, P. L. & Enochs, L. (1997). Reliability and validity evidence for the Middle School Self-Efficacy Scale. *Measurement and Evaluation in Counseling and Development, 30*(1), 17-31.

[17] Adapted from *Motivation and Engagement Scale-Junior School*: Martin, A.J. (2012). *The Motivation and Engagement Scale (12th Edition).* Sydney, Australia: Lifelong Achievement Group.

[18] Adapted from *School Engagement Scale*: Fredericks, J.A., Blumenfeld, P., Friedel, J., &Paris, A. (2005). School engagement. In K.A. Moore & L. Lippman (Eds.), *What do children need to flourish?: Conceptualizing and measuring indicators of positive development*. New York, NY: Springer Science and Business Media.

[19] Counts include duplicated students who participated in the course multiple times across the school year.

[20] School names are hidden in the presentation of outcomes and participation rates.

Schools 4, 5, and 6 had two classes implementing the REDC per quarter/semester. Consequently, the number of students participating in REDC in the latter three schools was greater, together making up 78% of the participating students. In addition, School 1 and School 3 were on a semester schedule; Schools 2, 4, 5, and 6 were on a quarter schedule.

Table 7: REDC Participation Numbers per School

School	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	***TOTAL***
School 1	0		49		***49***
School 2	16	24	21	21	***83***
School 3	24		16		***40***
School 4	48	58	58	51	***215***
School 5	49	42	47	45	***183***
School 6	61	48	49	51	***209***
TOTAL	***198***	***172***	***240***	***169***	***779***

Note: Quarters 1 and 2 occurred during Fall Semester 2013, and Quarters 3 and 4 occurred during Spring Semester 2014.

Participant Demographics

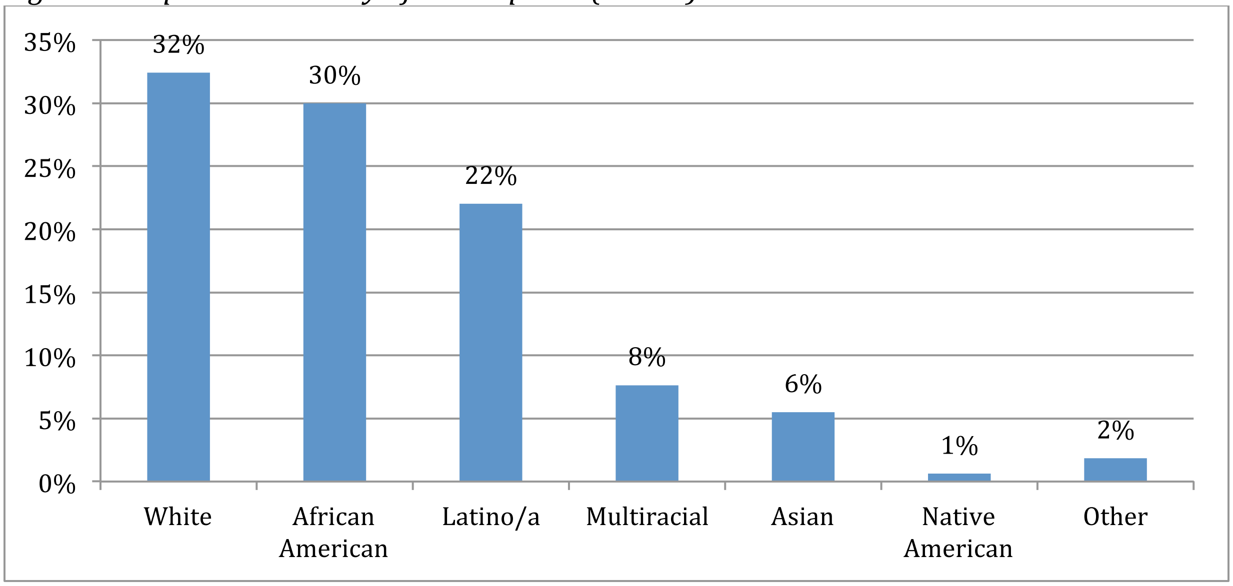
Although 779 students participated in the courses, in order for their data to be reported, both student assent and parental permission was required. Demographic information was self-reported through the survey; therefore, data was available only about those students who chose to report this information, as well as had parental permission and provided assent to be in the study.

The sample consisted of more females than males (56% and 44%, respectively). This imbalance was partially influenced by one school being an all-girls institution. However, the three schools that had the largest participation numbers (Schools 4, 5, and 6) all had slightly more female participants than male participants.

Ethnically, the largest groups of students represented among the REDC participants were either White (32%) or African-American (30%), followed by Latino/a (22%). Students who indicated having multiple-ethnic/racial identities made up 8% of the participants, followed by Asian (6%) and Native American (1%). The proportion of students per ethnic group showed great variance across schools, as is suggested by the demographic information per school presented earlier in this report.

Demographic information of participants is not disaggregated per school as this could allow school identification.

Figure 1: Reported Ethnicity of Participants (n=327)



Learning Environments: Teacher Survey

At the conclusion of each Unit, teachers were asked to complete a feedback survey. All teachers (n=6) provided feedback through the survey at least once per semester that a REDC Unit was implemented. As part of this survey, teachers were asked to identify events/occurrences during the school year that might have negatively or positively impacted the students' experience of the course or the students' learning. Commonly noted negative occurrences primarily focused on interruptions. School assemblies and standardized testing were often scheduled during these class times. In addition, an unusual number of weather-related school closings interrupted the curriculum during Quarter 3. Positive occurrences noted by the teachers included science fairs and STEM clubs, such as First Lego Leagues (FLL) and Girls Adventures in STEM. A series of rating items were presented to the teachers through the survey. When asked to indicate whether they felt prepared to teach the REDC material, 50% of teachers agreed and 50% strongly agreed.

Because REDC provided additional exposure to math and science concepts taught in the specific content courses, additional impact in student learning was expected to occur if REDC teachers worked with other teachers at their school. However, ratings by REDC teachers indicated they did not align their teaching with the topics occurring in other content classes, with 50% disagreeing and 50% responded in the neutral. Teachers did indicate different levels of collaboration with the science and mathematics teachers at their school. One teacher indicated that he/she discussed examples of forces and how force diagrams were taught; another teacher indicated that he/she wanted to make certain the same vocabulary that appeared in the standards was used in his/her class. A third teacher had the science teacher visit the REDC class to observe the content being covered. Finally, a fourth teacher received a science workbook from the science teacher so that the engineering teacher could see how the topics were explained.

Impact of REDC

Differentiating the Units

The eight content standards that are addressed by the implemented Units and measured through the content assessment were:

Biomechanics Unit:

1. Physical Science GPS - Students will investigate the relationship between force, mass, and motion of objects.
    a. Determine the relationship between velocity and acceleration.
    b. Demonstrate the effect of balanced and unbalanced forces on an object in terms of gravity, inertia, and friction.
2. Math CCGPS
    a. Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways.
    b. Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

EMR Unit:

1. Physical Science GPS – Students will explore the nature of sound and electromagnetic radiation.
    a. Identify the characteristics of electromagnetic and mechanical waves
    b. Describe how the behavior of light waves is manipulated causing reflection, refraction, diffraction, and absorption.
2. Math CCGPS– Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities (e.g., use millimeters per year for seafloor spreading). Interpret scientific notation that has been generated by technology).
3. Math CCGPS - Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways.

Both Units: Engineering and Technology

1. The students will develop an understanding of the Universal Systems Model.
2. The students will develop an understanding of how humans interact with systems.
3. The students will develop an understanding of how systems evolve from one stage to another.
4. The students will recognize relationships among technologies and assess the impact of technological systems.

Of the four REDC Units available for implementation in the classroom, the teachers were allowed to choose to implement the units. The teachers chose the Biomechanics and Electromagnetic Radiation (EMR) Units. Implementation of each unit per school is described in the table below.

Table 8: REDC Unit Implementation per School, 2013-14

School	Quarter 1	Quarter 2	Quarter 3	Quarter 4
School 1	REDC Not implemented		Biomechanics (semester)	
School 2	Biomechanics	Biomechanics	Biomechanics	Biomechanics
School 3	Biomechanics (semester)		EMR (semester)	
School 4	Biomechanics	Biomechanics	EMR	EMR
School 5	Biomechanics	Biomechanics	EMR	EMR
School 6	Biomechanics	Biomechanics	Biomechanics	Biomechanics

The most frequently chosen Unit by the teachers was the Biomechanics Unit. In the case of three teachers, this was the only unit they implemented. The EMR Unit was implemented by three teachers during second semester only.

Student Knowledge Gain

Pretest and posttest data was available for a total of 291 students who participated in the courses across the schools. This represents 37% of the total population of students who participated in the REDC course. The loss of sample is primary the result of lack of Parental Permission, which was required per our IRB (Institutional Review Board) for participation in the study. Students also had to provide their assent to participate. Finally, both pretest and posttest data had to be available for a student in order to be included in the analysis. The primary reason for a student to be missing either the pretest or the posttest was due to late enrollment in a course or early withdrawal, as the tests were administered during the first and last weeks of the units. It is considered unlikely that there was a systematic reason for students to be missing a test, and is therefore unlikely to have an impact upon the results of the pretest/posttest comparisons. Regardless, students who were not exposed to the complete curriculum were not appropriate to be included in the pretest/posttest comparisons. The participation rates per school are presented in Table 9 below.

It should be noted that students had the possibility of being enrolled in the REDC course more than once over a school year. Across the schools, this information was captured through self-report items during Quarters 2 through 4. A total of 12 respondents (4%) indicated having participated in the course during one of the previous quarters/semesters. Of these 12 students, 8 completed the pretest and posttest during more than one quarter/semester. Removing these duplicated students from the sample had no impact upon the findings of statistical significance. It should be noted that no students took the pretest or the posttest more than once during one REDC Unit (e.g., quarter/semester).

Table 9: Number of Students with Data Available for Pretest and Posttest per School

School	Sample Size	Participation Rate
1	13	27%
2	23	28%
3	13	33%
4	82	38%
5	72	39%
6	79	38%
Total	291	37%

Overall, students answered just under half (48%) of the 18 items correctly at the pretest. Improvements in content knowledge, though modest, were apparent in every school. Overall, students showed an average increase in percent of items answered correctly of 5%. This increase is significant[21]. The effect size for this increase is 0.28, which is considered small[22]. This increase varied across schools, with School 1 showing the greatest increase of 12%.

When examining the students' performance on items related to content covered by the Biomechanics Unit only, which was the unit most commonly implemented by the teachers, the overall average increase in percent of items answered correctly is 8% (increasing from 49% to 57%). For these items, School 1 showed the greatest increase at 19% followed by School 3, which showed an increase of 16%.

Overall, the specific items that showed the greatest increases were related to interpreting slope of the line, with students showing a 16% increase in the average percent of students that answered the item correctly on the pretest to the posttest, and a 10% increase in the item in which students identified a line with a positive slope. Additionally, the item asking students to identify the longest wavelength from an oscilloscope output showed a 13% increase. A chi-square test of independence was calculated comparing the frequency of correct responses on the pretest and the posttest for these three items. All three were found to be significant[23].

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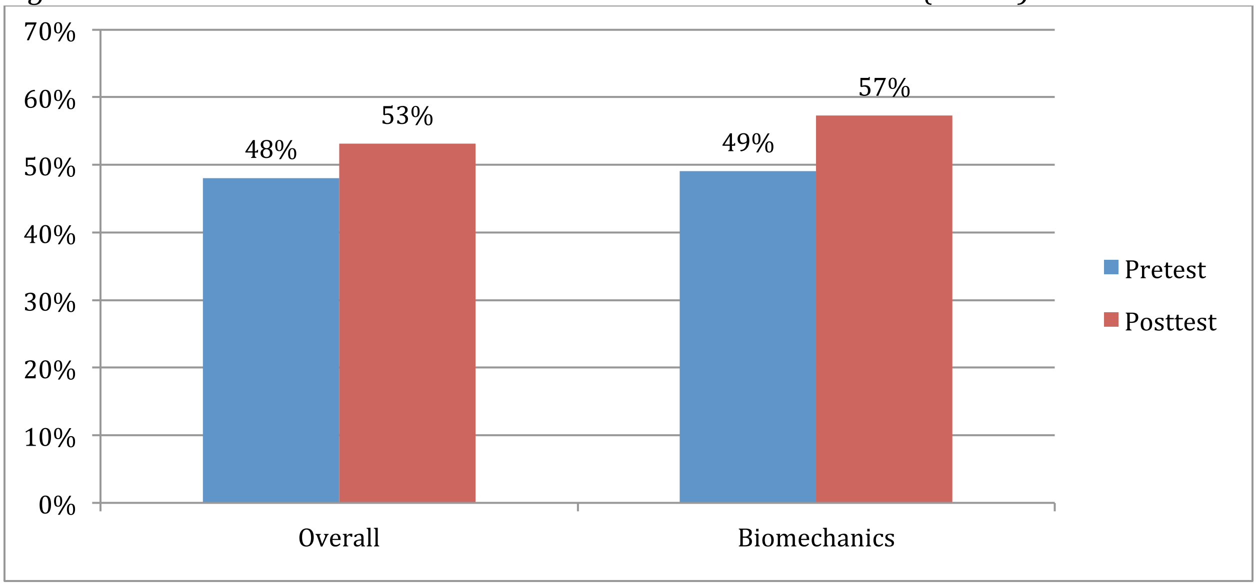
[21] Paired samples t-test: $t=5.33$, $df=290$, $p<.001$

[22] Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (second ed.). Lawrence Erlbaum Associates.

[23] $X^2(1)=22.5$, $p<.01$; $X^2(1)=12.39$, $p<.01$; $X^2(1)=24.9$, $p<.01$, respectively

Figure 2: Overall Percent Correct on the Content Pretest and Posttest (n=291).



Non-Cognitive Skills

Across all of the schools, a total of 330 students had both pre-survey and post-survey data available for analysis, which is 42% of the total number of students who participated in REDC. This number includes 5 students who completed the survey during two different quarters/semesters; therefore, the number of unique students was 225. A comparison of analyses that included these duplicated students to analyses that did not include these students showed no significant impact upon the results. It should be noted that no students took the pretest or the posttest more than once during one REDC Unit (e.g., quarter/semester). Pre/post surveys are located in the Appendix. Just as with the pretest and posttest, the loss of data is primarily the result of lack of Parental Permission, which was required per our IRB (Institutional Review Board) for participation in the study, as well as the students had to provide assent. To be included, a student must also have a pre-survey and post-survey available. The primary reason for a student to be missing either the pre-survey or the post-survey was due to late enrollment in a course or early withdrawal, as the surveys were administered during the first and last weeks of the units. The response rates were slightly higher for the survey than for the assessment. The participation rates per school are presented in the table below.

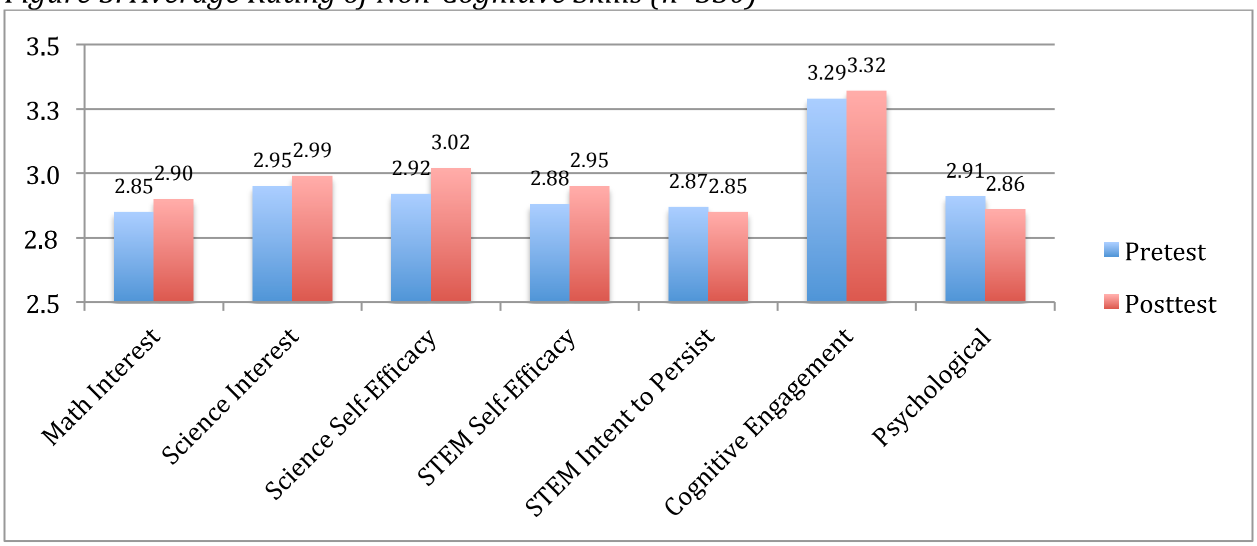
Table 12: Number of Students with Data Available for Pre-survey and Post-survey per School

School	Sample Size	Participation Rate
1	24	49%

2	25	30%
3	13	33%
4	97	45%
5	85	46%
6	86	41%
Total	330	42%

Ratings on the items of the survey ranged from Strongly Disagree (=1) to Strongly Agree (=4). The change for all scales was small and non-significant with the exception of Science Self-Efficacy and STEM Self-Efficacy. For these two scales, a positive and significant change was found (p<.05).

Figure 5: Average Rating of Non-Cognitive Skills (n=330)



Note: Ratings ranged from 1 = Strongly Disagree to 4 = Strongly Agree.

Table 13: Average Rating of Non-Cognitive Skills

Construct	Pre	Post	Change	N	Significance
Math Interest	2.85	2.90	0.05	330	ns
Science Interest	2.95	2.99	0.04	329	ns
Science Self-Efficacy	2.92	3.02	0.10	321	p<.05
STEM Self-Efficacy	2.88	2.95	0.07	325	p<.05
STEM Intent to Persist	2.87	2.85	-0.02	325	ns
Cognitive Engagement	3.29	3.32	0.03	326	ns
Psychological Engagement	2.91	2.86	-0.05	325	ns

School Level Discussion

The following section presents descriptive information for each school, although it is not possible to make a causal link between the descriptions and the changes in assessment scores or non-cognitive skills. The information presented describing the implementation of the Units per school was gathered from the Teacher Surveys, which were administered at the conclusion of each unit.

Figure 6: Performance on Overall Pre and Post-Content Assessments per School

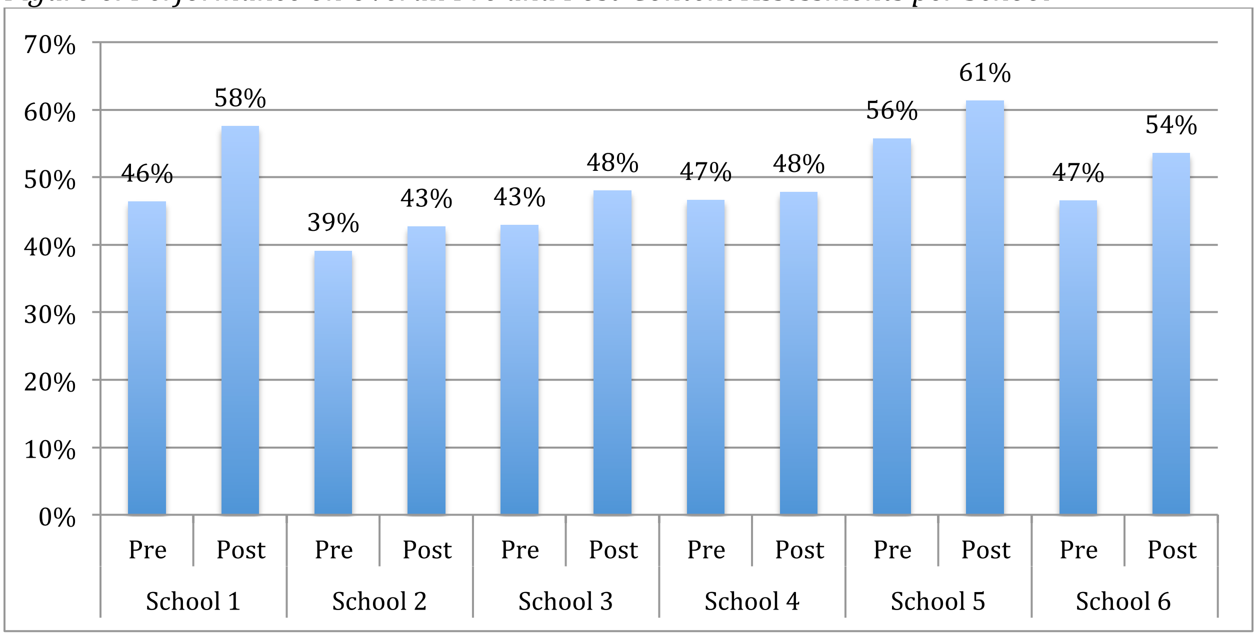


Table 14: Average Change in Non-Cognitive Constructs per School

Non-Cognitive Skill	School 1	2	3	4	5	6
Math Interest	-0.18	0.20	-0.05	0.01	0.10	0.07
Science Interest	0.07	-0.07	0.03	0.08	0.03	0.05
Science Self-Efficacy	0.09	-0.04	0.09	0.11	0.09	0.16
STEM Self-Efficacy	-0.03	-0.04	0.17	0.06	0.07	0.09
STEM Intent to Persist	-0.19	-0.01	0.12	-0.04	-0.08	0.07
Cognitive Engagement	-0.12	-0.03	0.21	0.03	0.00	0.09
Psychological Engagement	-0.08	-0.08	0.05	-0.07	-0.10	0.04

The four units of the Robotics and Engineering Design Curriculum were iteratively designed and implemented using the schedule of the REDC Task Plan. Per the Task Plan, the Units were collaboratively (GA Tech/1st Cohort Teachers) and iteratively developed for the first two years of the project. The detailed outline of each of the units was completed by November 2012. Since the units were designed to be independent, the first year cohort teachers were given discretion on which units to teach during the second year. The second year cohort teachers were given discretion based on their comfort-level with the material.

A description of implementation by individual school follows.

School 1

Pre -Existing CTAE Class Descriptions: Exploratory Module based courses in engineering and technology education prescribed by the Georgia Department of Education.

Academic Year 12-13: The curriculum was taught in the CTAE class. The class was scheduled to change students every nine-week grading period. The curriculum was implemented for the first 9-weeks of the Biomechanics Unit. During the implementation of the first 9-weeks, personnel issues arose: the teacher left the position and the school was not able to fill the position.

Academic Year 13-14: The curriculum was taught in the CTAE class. The school was able to fill the position, left vacant since the previous school year, during the 1st nine-week grading period. The first year teacher was trained during the 2nd nine-week grading period. The class was scheduled for semester rotation. The teacher taught the Biomechanics Unit for the 4th nine-week grading periods.

Summary of School Level Information

- Test Sample Size = 13
    - Overall increase in the average percent correct from the pre-assessment to post-assessment: 11%
- Survey Sample Size = 24
    - Non-cognitive: Positive change in Science Interest (0.07) and Science Self-Efficacy (0.09). Negative/no change on all other constructs.

This teacher was implementing the REDC for the first time. The implementation was limited to one quarter of Biomechanics. This particular teacher had received a large amount of professional development in implementing science and math content in an engineering course. She had not been able to participate in the summer training on the curriculum, however, but received training and coaching by members of the curriculum design team during the school year. Through the teacher survey, the teacher reported feeling unprepared to teach some of the aspects of the course as intended. Potential explanations for the success in the content assessment but not in the non-cognitive skills other than science interest and science efficacy might be related to her comfort teaching the content but not with the activities themselves, as they were relatively unfamiliar. However, the teacher indicated that her students had challenges with understanding force and motion diagrams, explaining the slope, and calculating velocity and speed.

School 2

Pre - Existing CTAE Class Descriptions: Exploratory Module based courses in engineering and technology education prescribed by the Georgia Department of Education.

Academic Year 12-13: Did not participate

Academic Year 13-14: The curriculum was taught in the CTAE class. The class was scheduled to change students every nine-week grading period. The teacher of the class was assigned to teach CTAE classes at the middle school and high school. The school offered one class that rotated students every nine-week grading period. During the 1st nine-week grading period the instructor's class time was changed to 40 min class periods. The Biomechanics Unit was taught each grading period. Time constraints dictated the units taught with major adjustments.

Summary of School Level Information

- Test Sample Size = 23
    - Overall increase in the average percent correct from the pre-assessment to post-assessment: 4%
- Survey Sample Size = 25
    - Non-cognitive: Positive change in Math Interest (0.2). All other constructs showed negative/no change.

The teacher in this school was implementing the course for the first time. This teacher implemented Biomechanics during all four quarters. This teacher faced exceptional challenges regarding time constraints, resulting in the inability to cover all topics as designed. The time constraints were related to initially short class periods of 40 minutes that were further reduced to 30 minutes due to CRCT preparation and testing. This resulted in a "more compact" version of the course being formulated and provided to him/her. In addition, the teacher was also beginning a new curriculum in both the 6th and 7th grades. However, the teacher noted that students were making connections with the content being taught in other courses.

School 3

Academic Year 12-13: The curriculum was taught in the Math Department as a connections class. The school did not offer any class in the CTAE strand. Due to several scheduling and administrative challenges, one class was taught for the calendar year on a semester rotation. For the 1st and 2nd nine-week grading periods, the curriculum implemented was the Biomechanics Unit. For the 3rd and 4th nine-week grading periods, the EMR unit was implemented.

Academic Year 13-14: The curriculum was taught in the Math Department as a connections class. One class was taught for the calendar year on a semester rotation. For the 1st and 2nd nine-week grading periods, the curriculum implemented was the Biomechanics Unit. For the 3rd and 4th nine-week grading periods, the EMR unit was implemented. The choice of units and length were the instructor's choice due to the teacher's assessment of the students.

Summary of School Level Information

- Test Sample Size =13
    - Overall increase in the average percent correct from the pre-assessment to post-assessment: 5%
- Survey Sample Size = 13
    - Non-cognitive: Positive Change in all constructs but Math Interest.

This teacher had a full semester to implement the Biomechanics Unit and then the EMR Unit during the 2013-2014 academic year. The teacher also participated in the pilot of the curriculum; therefore, this is the second year of exposure to REDC. This teacher indicated that she/he supplemented science and mathematics concepts with his/her own opening and closing questions, and additional activities in order to meet the requirements of the school. Finally, the teacher noted being required to include formative assessments in the course by the school.

During the semester the teacher taught Biomechanics, he/she noted that one of the classes was off-balance due to a last minute change from attending a drama course to the engineering course, but "most adjusted and got into curriculum." In addition, the teacher noted that "students were able to take math concepts and to the math class. They were excited they had the correct answers."

During the second semester, the teacher noted that she "mostly" implemented two of the investigations of EMR. The teacher noted that the students "did really well and the most time consuming difficult activity for them was the research. It took them much longer than I wanted." The teacher also noted the interruption of snow days early in the semester as well as a number of 8th grade activities outside of the course.

School 4

<u>Pre -Existing CTAE Class Descriptions</u>: Exploratory Module based courses in engineering and technology education prescribed by the Georgia Department of Education.

<u>Academic year 12-13:</u> The curriculum was taught in the CTAE class. The class was scheduled to change students every nine-week grading period. The Biomechanics Unit was taught the 1st and 2nd nine-week grading period classes. The EMR Unit was taught the 3rd and 4th nine-week grading period.

<u>Academic year 13-14:</u> The curriculum was taught in the CTAE class. The class was scheduled to change students every nine-week grading period. The 1st and 2nd nine-week grading period classes were taught the Biomechanics Unit. The 3rd nine-week grading period class was taught the EMR Unit. For the 4th nine-week grading period, the EMR was taught due to teacher preference.

Summary of School Level Information

- Test Sample Size = 82

    - Overall increase in the average percent correct from the pre-assessment to post-assessment: 1%
- Survey Sample Size = 97
    - Non-cognitive: Positive change in all constructs other than STEM Intent To Persist and Psychological Engagement.

This teacher participated in the pilot and was, subsequently, familiar with all aspects of the course. He/she implemented Biomechanics during Quarter 1 and 2 and the EMR Unit during Quarter 3 and Quarter 4. During both Biomechanics quarters, the teacher indicated through the Teacher Survey that he/she implemented everything with the exception of the final presentation. The teacher indicated that students had challenges understanding the force diagrams and calculating velocity and average velocity. The teacher noted that, typically, students in the advanced mathematics courses could calculate the formula while those in regular math could not, even having challenge calculating averages in general. This teacher lost three days during Quarter 1 due to personal issues. During Quarter 2, the students went on a field trip, had scoliosis testing, attended cultural performances, and the teacher had furlough days, all which reduced the amount of time in the class. Laptop problems were also a regular challenge for this teacher. The teacher also indicated through a rating scale on the survey that the school administration was neither supportive nor un-supportive ("neutral" on the 5-point scale).

During Quarters 3 and 4, the teacher did not implement the antenna investigation, particularly the mathematical formulas. This was due to snow days, CRCT testing, Award day, and personal leave by the teacher. A substitute conducted part of the curriculum while the teacher was out. The teacher experienced laptop problems again. The mission activities were all implemented fully. Science aspects were illustrated in the students' science course. He/she noted that some of the students were disinterested throughout the whole course, though, indicating that they were "Fine Arts" students.

School 5

<u>Pre -Existing CTAE Class Descriptions</u>: Exploratory Module based courses in engineering and technology education prescribed by the Georgia Department of Education.

<u>Academic Year 12-13:</u> Did not participate

<u>Academic Year 13-14:</u> The curriculum was taught as a Business/Computer Science/Technology connections class. The 1st and 2nd nine-week grading period classes, the Biomechanics Unit was taught. The 3rd and 4th nine-week grading period classes, the EMR Unit was taught.

Summary of School Level Information

- Test Sample Size = 72
    - Overall increase in the average percent correct from the pre-assessment to post-assessment: 6%

- Survey Sample Size = 85
    - Non-cognitive: Positive change in all constructs with the exception of STEM Intent To Persist and Psychological Engagement.

This was the first time this teacher had taught the content of this course. The teacher implemented Biomechanics during Quarters 1 and 2 and the EMR Unit during Quarters 3 and 4. During Biomechanics, she indicated through the Teacher Survey that she was unable to get to the presentations at the end of the course, and was not able to iterate the design during Quarter 2. The teacher noted that she/he was challenged with getting the students to understand the importance of accurate trials, and that the students were challenged with the unexpected amount of critical thinking required. The teacher noted putting extra attention in explaining the graphs to the students. The teacher indicated that the data logging activities were challenging to teach, as it was new to him/her. Also, teaching the force diagrams were challenging, as they were also new to the teacher. She/he noted that there were multiple interruptions in the course resulting in having time to cover everything being a challenge.

During the EMR Unit, this teacher was not able to iterate on the designs or do a formal presentation. He/she indicated having challenges with some of the software. In addition, the calculations related to waves were noted as difficult for students to complete and took more time than anticipated "to make sure they truly understood the importance in the calculations and how to do it." Some time was lost during the semester due to a field trip to Georgia Tech, a visit from 5th grade students, a high school play attendance, and the teacher had to attend a technology meeting.

School 6

<u>Pre -Existing CTAE Class Descriptions</u>: Technical Education programs are part of the "connections" block for middle school students. Technology Education, Computer Science, Family and Consumer Science, and Careers are possible offerings at middle schools. Students have the opportunity to develop skills that will be needed in high school and beyond.

<u>Academic year 12-13:</u> The curriculum was taught in the Math Department as a connections class. The principal wanted to continue the offering of the CTAE class to be in alignment with the county's middle schools. They were also interested in the comparison of the two classes. The school and county found it beneficial to have another academic based connections class that was designed to be an integrative and trans-disciplinary math and science class. Therefore, to participate in the program, the principal created a connections class that would feature the curriculum. The curriculum was implemented in 2 classes. The class was scheduled to change students every nine-week grading period. Both classes were taught the Biomechanics courses 1st and 2nd nine-week grading periods. Both classes were taught the EMR Unit for the 3rd nine-week grading period. For the 4th nine-week grading period, one class was taught the Biomechanics Unit and the other class was taught the Energy Unit.

Academic Year 13-14: The curriculum was taught in the Math Department as a connections class. The curriculum was implemented in 2 classes. The class was scheduled to change students every nine-week grading period. Both classes were taught the Biomechanics Unit 1st and 2nd nine-week grading periods. Due to the comparison study conducted the 3rd and 4th nine-week grading periods, both classes were taught the Biomechanics Unit again.

Summary of School Level Information

- Test Sample Size = 79
    - Overall increase in the average percent correct from the pre-assessment to post-assessment: 7%
- Survey Sample Size = 86
    - Non-cognitive: All constructs moved in the positive direction from pretest to posttest.

This teacher was a member of the pilot group as well as participated in developing training materials for the teacher training during the summer. This teacher indicated fully implementing all aspects of Biomechanics with the exception of the final presentation. The first semester was interrupted by scoliosis testing, picture day, and testing. He/she indicated that the force and motion is the greatest challenge for the students to understand because it is a new concept. Third quarter, this teachers' schedule changed to an alternating day schedule, reducing the number of sessions he/she had with the students each week. In addition, third quarter was interrupted by nine snow days. This resulted in a number of alterations to the course, but this teacher tried to choose to shorten aspects that she/he deemed were less important to their learning, particularly to understanding graphs of velocity.

Lessons Learned and Plans for the future

The lessons learned from the implementation of both cohorts are as follows:

- Administrative support is necessary for the effectiveness of implementation;
- Continued professional development support is needed through the second year of implementation;
- A point-of-contact for teacher support is ideal;
- Teachers should have some knowledge of problem based learning instruction;
- Teachers should have knowledge of the engineering design process;
- Teachers should have a willingness to implement new strategies and be comfortable with the challenges that may occur.

The RT3 Project plan has an end date of August 31, 2014. CEISMC/Georgia Tech will discontinue support for the curriculum after this date. Because of the need for professional development and support for teachers implementing the curriculum, it is recommended that such support is made available for the units and the use of instructional technology used during instruction. Because of the interest expressed by other schools and districts in this curriculum for CTAE and Connections Courses, it is recommended that the curriculum be extended to grades 6 and 7. Along with curriculum development to extend to all middle grades, additional units for each grade should be developed to meet the varied interests of the students.

Summary of Findings

- The administrator support at the school level is important to effectively implement REDC. The scope of this project did not allow a study of the key elements for fidelity of the implementation; However, our experience indicates that a **clear understanding of the components to effectively implement REDC is necessary for the effectiveness of implementation.** School level administrators expressed support for REDC but in several instances, their actions created barriers for implementation. For example, scheduling proved to be a problem in many schools. Administrators in some schools would change the nine-week duration to a semester long course with little notification to teachers; Therefore, course planning became an issue. In some settings, students were placed in the course without any prior knowledge they would be there. Instructional time was also decreased in some schools to accommodate other courses or schedules.

- The propensity for adopting a new curriculum, such as RECD, depends on teachers' attitudes towards or receptivity to that curriculum.[24] Although positive attitudes towards a curriculum innovation may not be an accurate predictor of implementation of an innovation, teachers' attitudes could be important in determining the successful implementation of a curriculum. Our experience during implementation suggests that **teachers should have a willingness to implement new strategies and be comfortable with the challenges that may occur. Teachers should be open to professional learning focusing on REDC course concepts including problem-based learning, the engineering design cycle, and use of innovative instructional technologies such as 3D printers and CAD (Computer-Assisted Design) software.** Some teachers were resistant to adapting their teaching styles. A particular issue was the planned collaboration between the CTAE teacher and the mathematics and science teachers. This collaboration occurred in only one school, which already had a commitment and school culture of collaboration.

- Improvements in content knowledge, though modest, were apparent in every school. Overall, the items of the content test that showed the greatest increases were related to interpreting slope of the line, with students showing a 16% increase in determining the slope of a line and a 10% increase in identifying a line with a

[24] Richardson, V. (1991) How and why teachers change. In S.C.Conley and B.S Cooper (eds.), The school as a work environment: Implications for Reform (Boston, MA: Allyn and Bacon), 66-87.

positive slope. **Students showed modest increases in content knowledge as evidenced by pretest/posttest scores.**

- **Among the seven Non-Cognitive skills that were captured through the student survey, two were found to increase significantly while the remainder showed no significant change.** The two constructs that showed significant change, both in the positive direction, were Science Self-Efficacy and STEM Self-Efficacy ($p < .05$). The constructs that did not show significant change were Math Interest, STEM self-efficacy, STEM Intent to Persist, Cognitive Engagement, and Psychological Engagement.

Appendix

Q4_Spring 2014_Post_Course Content Test

This assessment will help us find out what you have learned over this quarter while you were in the Robotics and Engineering Course. There are a total of 18 questions.

*Please provide the following information:

First Name: ____________________

Last Name: ____________________

*What is the name of your school?

- ○ Ben Hill County Middle School
- ○ Carver Road Middle School
- ○ Coretta Scott King Young Women's Academy
- ○ General Ray Davis Middle School
- ○ Lilburn Middle School
- ○ Woodstock Middle School

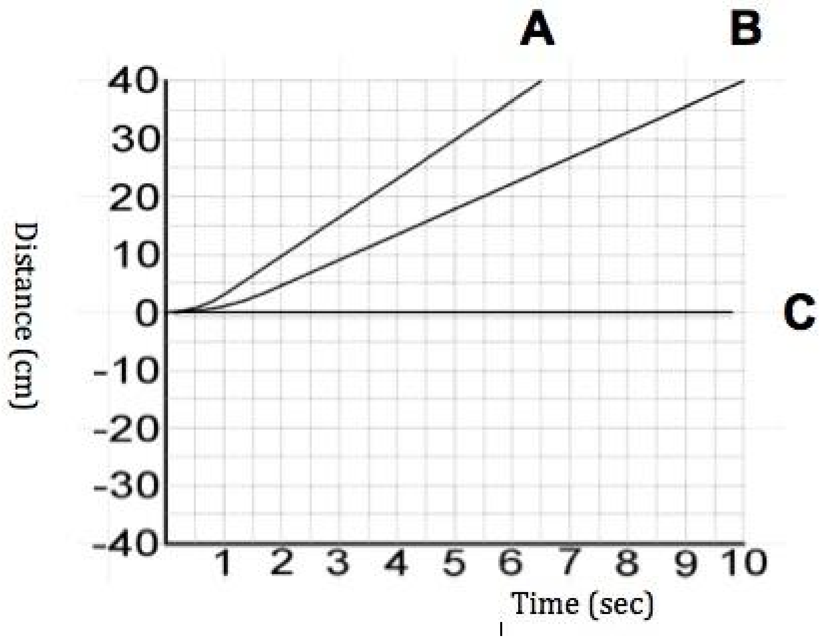
What math course are you currently taking?

- ☐ Introduction to Algebra (Pre-Algebra)
- ☐ Introduction to Geometry
- ☐ Algebra 1
- ☐ Geometry
- ☐ None of the Above

If you are not taking any of these classes, please let us know what you are taking:

____

Use this graph to answer the question below.



1) Which of the following statements best describes Robot C?

- ○ Robot C had the greatest velocity.
- ○ Robot C did not move.
- ○ Robot C travelled in a straight line.
- ○ Robot C travelled in reverse.

2) At the start of Robot A's and Robot B's graphed lines, there is a short curved section. What is a logical explanation?

- ○ Both robots were turning.
- ○ There is not enough information given to answer the question.
- ○ Both robots were accelerating.
- ○ Robot A was traveling faster than robot B.

3) The slope of the graphed lines is related to the robot's velocity in what way?

- ○ The greater the slope, the lower the velocity.
- ○ There is no relationship between slope and velocity.
- ○ There is not enough information to answer the question.
- ○ The greater the slope, the higher the velocity.

4) The visible part of the electromagnetic spectrum is a very small part of a broad range of waves. Which of the following statements is true?

- Radio waves have a higher frequency than visible light.
- Microwaves have a much shorter wavelength than visible light.
- X Rays have a higher frequency than visible light.
- Infrared waves have the lowest frequency of all waves.

5) As the wavelength of a wave increases, it's frequency will ________.

- Decrease
- Increase
- Remain the same
- Not enough information

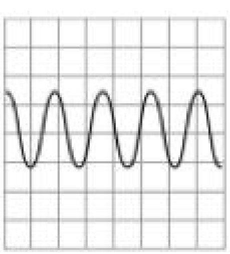
6) A low-frequency radio wave has a frequency of 250,000Hz. Which is the correct way to determine the wavelength? [Note: The speed of light = 3×10^8 meters per second]

- $250{,}000 / (3 \times 10^8) = 0.0008$
- $(3 \times 10^8) / 250{,}000 = 1200$
- $250{,}000 + (3 \times 10^8) = 300{,}250{,}000$
- $250{,}000 \times (3 \times 10^8) = 7.5 \times 10^{13}$

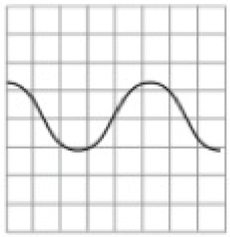
7) Engineers can use an oscilloscope to display the properties of a wave. Below are several pictures from an oscilloscope. Which of these pictures shows the wave with the longest wavelength?

- Picture A
- Picture B
- Picture C
- Not Enough Information

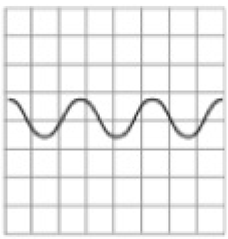
Picture A



Picture B



Picture C



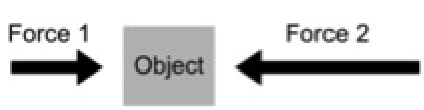
8) What is the wavelength of a radio wave that has a frequency of 1 × 10^5? [Note: The speed of light = 3 × 10^8 meters per second.]

- 4 X 10^{13}
- 3 X 10^{13}
- 3 X 10^3
- Not enough information

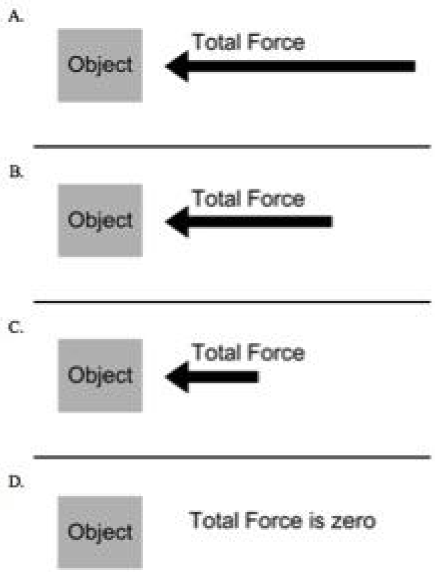
9) If an object on the table is not moving, what is true about all of the forces acting on the object?

- The force of gravity is the strongest.
- The force of gravity is the only thing holding the object in place.
- There are no forces acting on the object.
- All of the forces acting on the object balance each other.

10) In the drawing below, the arrows labeled Force 1 and Force 2 represent two forces acting on an object. The directions of the arrows show the directions of the forces, and the lengths of the arrows represent the strengths of the forces.



One of these pictures shows the total force acting on the object.



Which total force is equal to the two forces acting on the object?

- A
- B
- C
- D

11) Which of the following best describes how a light sensor guides a Lego robot to follow a line?

- It sends steering commands directly to the motors.
- It locates the center of a line using reflection.
- It shines a light on the line so the robot can follow it.
- It detects the edge of a line by measuring the reflections from the surface.

12) Which of the following sequence of events best represents the Universal Systems Model?

- Goal-Input-Process-Output-Feedback
- Input-Process-Output-Goal-Feedback
- Input-Process-Output-Feedback-Process
- Feedback-Input-Goal-Process-Output

13) Which of the following is ALWAYS true about a complex system?

- Complex systems are very expensive.
- Complex systems are designed by multiple engineers.
- Complex systems are difficult to understand.
- Complex systems are made up of many systems.

14) When a complex system fails to perform properly, what should you do first?

- Replace the most expensive part of the system.
- Take the entire system apart and put it back together again.
- Look at the data to see what subsystem is not performing properly.
- Design a new system that you think will perform better.

15) The solar panels needed to power your spacecraft continue to fail. As an engineer, first you examined the solar panels and discovered that the problem was caused by one of the gears, which was designed incorrectly. In the Universal System Model, what type of information did you gather?

- Plans
- Feedback
- Input
- Process

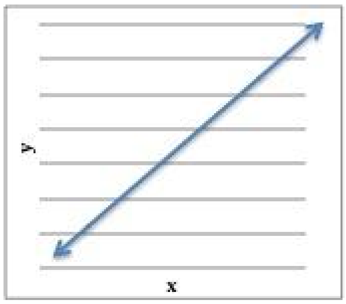
16) A certain wave on the border between microwaves and infrared waves has a frequency of 2,000,000,000,000 Hz. Rewrite this number using scientific notation.

- 2.0×10^{12}
- 2.0×10^{6}
- 2.0×10^{2}
- 2.0×10^{-6}

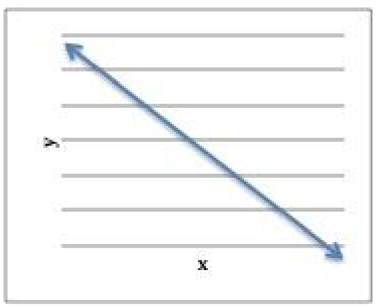
17) The following graphs display different relationships between variables x and y. Which graph displays a positive slope?

- Picture A
- Picture B
- Picture C
- Picture D

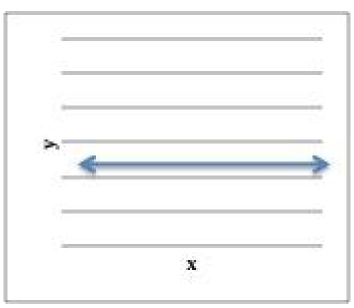
Picture A



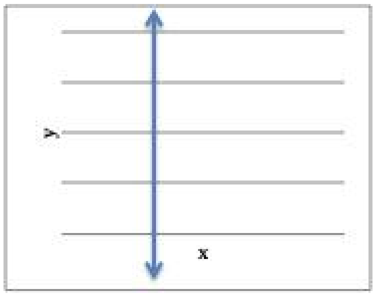
Picture B



Picture C

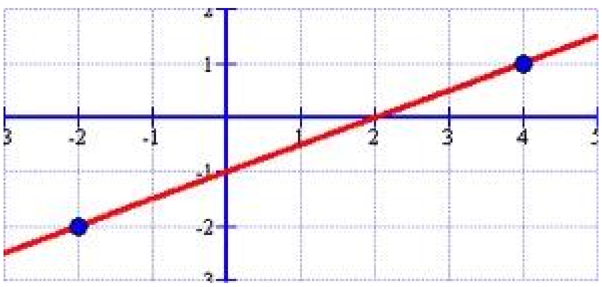


Picture D



18) What is the slope of the line shown in the graph below?

- 2
- 1/3
- 3
- 1/2



You have reached the end of this assessment. Thank you for your help!

Post Course Survey (Quarter 4)

The purpose of this survey is to discover how students feel about science, math, and engineering. Please complete all the questions as honestly as you can.

*1. Please provide the following information:

First Name:

Last Name:

2. What is the name of your school?

- Ben Hill County Middle School
- Carver Road Middle School
- Coretta Scott King Young Women's Academy
- General Ray Davis Middle School
- Lilburn Middle School
- Woodstock Middle School

3. Please tell us how much you agree with the following statements about Technology and Engineering.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I am interested in the work in technology class.				
I feel bored in technology class.				
I feel excited by the work in technology class.				
I like being in technology class.				
I can understand difficult ideas in technology.				
I can learn new ideas quickly in technology class.				
I intend to enter a career that will use technology.				
I am committed to study hard in my technology classes.				
I am determined to use my technology knowledge in my future career.				
I plan to take a lot of technology classes in high school.				

Post Course Survey (Quarter 4)

4. Please tell us how much you agree with the following statements about Math.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I find math interesting.	○	○	○	○
I think that I will use math in the future.	○	○	○	○
Math relates to my life.	○	○	○	○
Math is one of my favorite subjects.	○	○	○	○
I enjoy learning mathematics.	○	○	○	○
I am interested in the work in math class.	○	○	○	○
I feel bored in math class.	○	○	○	○
I feel excited by the work in math class.	○	○	○	○
I like being in math class.	○	○	○	○
I can understand difficult ideas in math.	○	○	○	○
I can learn new ideas quickly in math class.	○	○	○	○
I intend to enter a career that will use math.	○	○	○	○
I am committed to study hard in my math classes.	○	○	○	○
I am determined to use my math knowledge in my future career.	○	○	○	○
I plan to take a lot of math classes in high school.	○	○	○	○

Post Course Survey (Quarter 4)

5. Please tell us how much you agree with the following statements about Science.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I enjoy learning science.	○	○	○	○
The science I learn relates to my personal goals.	○	○	○	○
I like to do better than other students on science tests.	○	○	○	○
If I am having trouble learning science, I try to figure out why.	○	○	○	○
I expect to do as well as or better than other students in science.	○	○	○	○
I am confident I will do well on science labs and projects.	○	○	○	○
I find learning science interesting.	○	○	○	○
The science I learn is relevant to my life.	○	○	○	○
I believe I can master the knowledge and skills in my science course.	○	○	○	○
The science I learn has practical value for me.	○	○	○	○
I like science that challenges me.	○	○	○	○
I am confident I will do well on science tests.	○	○	○	○
I believe I can earn a grade of “A” in my science course.	○	○	○	○
I am interested in the work in science class.	○	○	○	○
I feel bored in science class.	○	○	○	○
I feel excited by the work in science class.	○	○	○	○
I like being in science class.	○	○	○	○
I can understand difficult ideas in science.	○	○	○	○
I can learn new ideas quickly in science class.	○	○	○	○
I intend to enter a career that will use science.	○	○	○	○
I am committed to study hard in my science classes.	○	○	○	○
I am determined to use my science knowledge in my future career.	○	○	○	○
I plan to take a lot of science classes in high school.	○	○	○	○

Post Course Survey (Quarter 4)

6. Please tell us how much you agree with the following statements.

	Strongly Agree	Agree	Disagree	Strongly Disagree
If I try hard, I believe I can do my schoolwork well.	○	○	○	○
If I can't understand my schoolwork, I keep trying until I do.	○	○	○	○
If I don't give up, I believe I can do schoolwork that is hard.	○	○	○	○
When I'm taught something that doesn't make sense, I spend time trying to understand it.	○	○	○	○
What I'm learning in my classes will be important in my future.	○	○	○	○
When I do schoolwork, I check to see whether I understand what I'm doing.	○	○	○	○
Learning is fun because I get better at something.	○	○	○	○
When I do well in school, it's because I work hard.	○	○	○	○
I plan to continue my education following high school.	○	○	○	○
Going to school after high school is important.	○	○	○	○
School is important for achieving my future goals.	○	○	○	○
My education will create many future opportunities for me.	○	○	○	○
I am hopeful about my future.	○	○	○	○

Demographic Information

7. Are you...

○ a boy

○ a girl

8. Are you... (select all that apply)

☐ African American

☐ Asian

☐ Hispanic/Latino

☐ Native American/Alaskan Native

☐ White

☐ Other

If Other, please specify

[ ]

You have reached the end of this survey. Thank you for your help!