

5-31-2015

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Relevant Education in Math and Science (REMS): K-12 STEM Outreach Program using Industrial Engineering Applications

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Matthew Marshall is an Associate Professor in the Industrial and Systems Engineering Department at Rochester Institute of Technology. He received a Ph.D. in Industrial and Operations Engineering from the University of Michigan in 2002. He is director of the Human Performance Laboratory at RIT and his research interests include the biomechanics of sign language interpreting and the ergonomic design of consumer products.

Dr. Jacqueline R. Mozrall, Rochester Institute of Technology (COE)

Dr. Jacqueline Mozrall is currently serving as Interim Dean of Saunders College of Business. Prior to joining the Saunders College as the Interim Dean, Dr. Mozrall served as Professor and Senior Associate Dean of the Kate Gleason College of Engineering. She worked closely with the Dean to assist in achieving college level goals, including diversifying the student body and faculty, supporting excellence in undergraduate and graduate education, fostering research and creating strong connections with employers and alumni. Jacquie has been a member of the management team for the Women in Engineering Program at RIT for more than 10 years. Since this time, there has been more than a tripling in the number of women in the entering class. She has been actively engaged in program assessment for more than 10 years, serving as a program evaluator and training mentor for the Accreditation Board for Engineering and Technology (ABET). She is also executive director and principal investigator of a \$420,000 Toyota USA foundation grant to support the development of in-lab and on-line activities linking K-12 STEM curriculum to real-world engineering problems.

Prior to becoming Associate Dean, Jacquie served as the Department Head of Industrial and Systems Engineering (ISE) at RIT from 2000-2010. During her tenure as department head, she had the pleasure to work with a dedicated group of faculty and staff to further strengthen the department's reputation for excellence in undergraduate education while significantly increasing engagement in graduate education and research. Strong relationships with key industry partners and alumni were created, including the establishment of the Toyota Production Systems Lab.

Ms. Jodi L. Carville, Women in Engineering at Rochester Institute of Technology

Jodi Carville is the Director of the Women in Engineering Program at RIT. She is responsible for the initiatives to inspire, educate, recruit, support and retain girls and women engineering students focused on engineering careers. She has a BS in Industrial Engineering and has worked with IBM and Kodak as an engineer and pursued a career in sales and marketing with both Kodak and Learning International. During her career sabbatical to raise her two boys, Jodi ran a successful direct sales business for 16



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years; marketing children's educational products that inspire learning. She recruited and trained women to be business owners and served as a speaker and trainer at conferences and events across the country. She serves on the RIT K-12 Advisory Board, is active with RIT Community and events, is President of the Society of Women Engineers Rochester Section, and enjoys long distance biking, travel, gardening, sporting events and family. <https://rit.edu/women>

Relevant Education in Math and Science (REMS): K-12 STEM Outreach Program using Industrial Engineering Applications

Abstract

Relevant Education in Math and Science (REMS) is a university-led STEM outreach program designed to use real-world industrial engineering problems to make 5th – 12th grade math and science fun and meaningful for students. In this work, we present the nine current engineering lab activities, developed in both in-lab and on-line format consisting of three different real-world contexts: competitive manufacturing, distribution, and healthcare. These activities are linked to curricular subject standards found in math and science at elementary, middle and high school grade levels. In addition, we present the multi-phased design, development, and assessment and evaluation process that was utilized to produce this program, including the results of over 1,300 surveys completed by students and teachers who have participated in the program activities.

1. Introduction

Connecting math and science concepts to real-world applications can help to generate student interest in STEM disciplines and careers. There have been significant outreach efforts to engage students in STEM-related activities, primarily with the intent of generating interest in STEM fields, but these efforts are not necessarily intended to teach specific K-12 math and science concepts. In this research, we present the design, development, and assessment of a university-led outreach program to address these needs. The presented work is focused on identifying and linking 5th – 12th grade math and science concepts for solving real-world industrial engineering problems.

Relevant Education in Math and Science (REMS) (<http://www.rit.edu/kgcoe/rem>) is an outreach program established by the Kate Gleason College of Engineering at Rochester Institute of Technology (RIT). REMS is a program designed to use real-world industrial engineering problems to make 5th – 12th grade math and science fun and meaningful for students. The goals of the REMS program are to: (a) create an effective math and science curriculum for grades 5–12 with a hands-on industrial engineering focus; (b) increase the number of 5th – 12th grade math and science teachers using age-appropriate teaching modules linking math and science to real-world industrial engineering challenges; and (c) increase the number of students who have access to fun, age-appropriate hands-on activities that link math and science to real world industrial engineering problems.

The curriculum is designed to provide students with an improved understanding and retention of mathematical and scientific concepts through the use of relevant laboratory lessons based upon real-world scenarios. On-line activities have also been developed that capture the essence of the in-lab laboratory experiences. These on-line interactive activities provide access to a broad national audience of teachers and students. Through participation in REMS activities, students can realize important connections between math and science concepts and real-world problems to stimulate their curiosity and interest in industrial engineering-related fields.

In this work, we present the nine current engineering lab activities, developed in both in-lab and on-line format. Three different real-world contexts: competitive manufacturing, distribution, and healthcare, serve as the backdrop for these activities (Table 1). These activities are linked to the different curricular subject standards found in math and science at different grade levels (i.e., elementary, middle and high school). The on-line format versions of the activities are designed to be used by teachers to serve as actual classroom lessons. In addition, we present the multi-phased design, development, and assessment and evaluation process that was utilized to produce this program, including the results of over 1,300 surveys completed by students and teachers who have participated in these lab activities.

Table 1. Summary of activities and examples of the curricular subjects that each activity covers.

	Activity	Description	Curricular Subjects
Contemporary Manufacturing	1) Skateboard Assembly – Cycle Time	Demonstrates the concept of 'cycle time' within a basic assembly line, which is the time it takes to assemble a part or product. Students gain an appreciation for how changing, or redesigning, the work impacts the cycle time.	<ul style="list-style-type: none"> Comparing rational numbers Calculating averages Percent change & cumulative % change Solving linear equations
	2) Skateboard Assembly – Line Balance	Demonstrates the process of “balancing” an assembly line, which is designing the same amount of work content, or time, at each workstation.	<ul style="list-style-type: none"> Rounding Using formulas Slope Solving linear equations
	3) Skateboard Assembly – Performance Testing	Allows students to analyze data from performance testing on skateboards. Students use skateboards and ramps to demonstrate concepts of potential and kinetic energy.	<ul style="list-style-type: none"> Potential and kinetic energy, friction Interpolation/Extrapolation Calculating percent error Graphing, Line of best fit
Distribution and Logistics	4) Meal Picking	Introduces systems for meal picking at distribution centers for patient cafeterias in hospitals, airline meal services, etc.	<ul style="list-style-type: none"> Independent/dependent variables Calculating averages Analyzing data Linear equations
	5) Ergonomic Design	Demonstrates how systems that lack ergonomics impact the user. Students learn how to collect and use data on human dimensions for the purposes of design.	<ul style="list-style-type: none"> Ordering rational numbers Measures of central tendency Box-and-whiskers plot Standard deviation & normal distribution
	6) Household Container Recycling	Allows students to analyze design systems for recycling household containers using single stream processes at materials recovery facilities.	<ul style="list-style-type: none"> Multiplying decimals Unit conversion Bar graphs Modeling using cost analysis
Healthcare	7) Patient Flow	Introduces students to the analysis of patient flow in hospital and other health care settings. Students simulate a walk-in health care clinic and collect data to analyze its design.	<ul style="list-style-type: none"> Creating and using histograms Using formulas Calculating percentages Making predictions
	8) Ergonomic Picking	Explores how good ergonomic design of a medical supply distribution center improves both productivity and ease-of-use of the system.	<ul style="list-style-type: none"> Collecting and analyzing data Multiplying whole numbers Rounding decimals Converting units of time
	9) Hazmat Disposal	Explores methods used for sorting medical waste; analyzes disadvantages of incorrect disposal including cost of errors; students develop ideas to make sorting easier and more efficient.	<ul style="list-style-type: none"> Adding, subtracting, multiplying integers Comparing numerical values Rounding Reading tables

The remainder of the paper presents related research work and outreach programs (section 2), the methodology used in the design and development of the REMS program (section 3), the REMS outreach program along with several activity descriptions (section 4), the assessment process and corresponding results (section 5), and our conclusions and recommendations for future work (section 6).

2. Related Work

University involved STEM outreach programs have been growing in recent years in response to studies showing a national need to get K-12 students involved in math and science activities with the desired outcome of students pursuing careers in STEM fields. The Colorado School of Mines introduced a STEM outreach program for K-12 students that involves a summer camp for students followed by graduate student support in the K-12 classrooms during the academic year^[1]. In addition, a K-12 outreach program called “STEM Academy” at Ohio Northern University utilizes one-day field trips for students to introduce them to hands-on science and engineering activities^[2]. The Arizona Science Lab at the University of Arizona utilizes a fieldtrip-based STEM outreach program which offers K-12 students opportunities to go through the full engineering design, build, and test cycle^[3]. These are examples of three of the various engineering outreach programs offered by universities across the U.S. that involve hands-on lab based activities to introduce students to STEM fields.

In addition to lab-based activities, there are a number of organizations that offer ideas for STEM activities K-12 students can experience via the Internet. Examples of these web-based activities include: *TEACH Engineering*^[4] (<https://www.teachengineering.org/>) which provides curriculum ideas for K-12 teachers with over 1000 theme based, standards-aligned engineering lessons and hands-on activities for use in science, engineering, and math classrooms; *Try Engineering*^[5] (<http://tryengineering.org/>) provides STEM resources for students, parents, teachers and guidance counselors; and *Design Squad Nation*^[6] (<http://pbskids.org/designsquad/>) provides lesson plan ideas, activities, animations, and video profiles to use in classrooms or at home.


The REMS outreach program that we have developed builds on these ideas for hands-on STEM activities for K-12 students and directly links the engineering activities to specific K-12 curricular subjects. Furthermore, the REMS activities provide lesson plans for teachers in both in-lab and on-line formats.

3. Design and Development Methodology for REMS Activities

The design and development methodology for the REMS activities centers on the goal of providing fun, age-appropriate, hands-on activities that link math and science to real world problems for students in grades 5-12. In this section we describe the design process we utilize to successfully develop and execute the REMS program including establishing the development team; establishing target math/science lessons for the REMS activities; utilizing an iterative development process for lab activities; implementing in-lab and on-line activities; and assessing the program.

The first step in the design process was to establish a core team of individuals with strong interest in engineering outreach for K-12 students. Our team includes several industrial and systems engineering faculty members; a college of engineering outreach staff member; a K-12 STEM education consultant and outreach liaison; and a group of graduate students. The team met regularly to design, develop, and assess the activities.

The fundamental aspect of each activity is identifying interesting and challenging industrial and systems engineering application and the specific corresponding STEM concepts found in standard K-12 curricula. An example activity involving cycle time analysis of a skateboard assembly line and the corresponding curricular subjects actively used in the activity is shown in Figure 1. For each activity, a full lesson plan is provided that includes the objectives, an estimate of time required, setup instructions, step by step lesson plan instructions, interactive activity worksheets, explanations of simulation videos (if applicable), and answer keys. The lesson plans are designed for each of the activities at three academic levels – elementary (grades 5-6), middle (grades 7-8), and high (grades 9-12) school.



Skateboard Assembly – Cycle Time

This activity demonstrates the concept of 'cycle time' within a basic assembly line, which is the time it takes to assemble a part or product. Work that is done to build skateboards is simulated through videos and animations, allowing students to experience the basic steps of the manufacturing, or assembly, process. Students can calculate the time it takes to assemble various parts of the skateboards well as the entire skateboard. Students can also gain an appreciation for how changing, or redesigning, the work can impact the cycle time.

Curricular Subjects:
Comparing Rational Numbers, Calculating Averages, Determining Percent Change and Cumulative Percent Change, Modeling (using Cost Analysis), Solving Linear Equations and Systems of Linear Equations

Figure 1: Example REMS activity description and corresponding curricular concepts.

The design of each in-lab and corresponding on-line activity involves a four stage process including: (1) Development; (2) Alpha Testing; (3) Beta Testing; and (4) Production/Continuous Improvement. The initial Development phase involves establishing the industrial and systems engineering application and corresponding curricular concepts. Then the interactive, hands-on student activities and initial lesson plans are developed. Next, Alpha Testing of the activity includes real-time execution of the activity with members of the team and others willing to participate. Alpha Testing provides feedback on the content, time-required, projections of perceived effectiveness and interest of the activities. In the next phase, Beta Testing, we introduce the activities to targeted students and teachers in grades 5-12. Beta Testing provides both formal and informal feedback on the activities through surveys and discussions with the participants. From this feedback, appropriate changes to activities are implemented leading to the final phase, Production/Continuous Improvement, and making the program activities generally

available for use. In the production/continuous improvement phase, we solicit feedback through surveys from students and educators to try to improve the activities on an on-going basis. The design and development of the on-line versions of the activities follows a parallel process.

The implementation of the REMS outreach program in terms of student and teacher participation has taken several avenues. The in-lab activities are conducted in our university labs and led by faculty and graduate students. Student participation has been primarily in groups including school or organization field trips or as part of university sponsored day or overnight camps for students. The on-line activities are provided through the university's college of engineering website and are available for anyone to use.

Throughout the design and development process, interaction with teachers has proven critical to the success of the program. We recognized that for the activities to be used by teachers, they needed to be relevant to the curriculum they are expected to cover, and be user friendly. When we started the development of the activities we met with teachers who told us if it took them more than a short amount of time to figure out how to use an exercise, they wouldn't use it. The documentation that was created for the activities and posted on the web site is detailed enough that the teachers (some of whom told us "remember, we are math teachers, we are not engineers") hopefully can set up what they need to do fairly quickly. In addition, in setting up the web site for the online activities, we considered that when teachers explore the internet for "real-life" activities that are relevant to their curricula, and they sort on words that are meaningful to them, the REMs web site will come up on the list. At one point in our development work, a teacher who helped us by supplying a list of example search words such as: "independent and dependent variables, critical thinking, problem solving, and engineering applications". As a result, the activities we use in some cases have multiple titles; one relevant to the physical activity, and one relevant to the academic content.

Finally, formal assessment of the REMS program has been conducted primarily through the use of surveys designed to obtain feedback from educator and students. The assessment provides information on the content of the lab activities as well as the interest level they provide. An analysis of the assessment data that we have gathered thus far is discussed in section 5.

4. Current State and Examples of REMS Activities

In this section, we present an overview of the current state of the REMS activities. Currently, nine activities have been developed and each activity includes an in-lab and online version. The in-lab activities predominately use the Toyota Production Systems Laboratory at RIT as the setting, while the online versions use one of two basic approaches to provide the targeted learning experience. In some cases, activities can be recreated in the classroom using supplies that are available in a typical K-12 classroom. In cases where it may not be possible to recreate the experience of the in-lab activities, computer simulations of the activities were created to enable access.

Table 1 lists each of the nine activities, along with a brief description of each activity and a listing of the curricular subjects that each activity covers. Coverage of the curricular subjects depends on the age and math-level of the students. In the next sections, we describe in more

detail the skateboard assembly line balancing and cycle time activities and the ergonomic design activity. The complete instructions, lesson plans, etc. for each of the activities listed in Table 1 are available at the following link: <http://www.rit.edu/kgcoe/remis> .

4.1 Skateboard Assembly: Line Balancing and Cycle Time Activities

A skateboard assembly line has been developed as the basis for several of the REMS activities to illustrate the engineering concepts encountered in a manufacturing environment relative to the design and efficient operation of production lines. For these activities, we are able to take advantage of the assembly line capabilities that are available in the Toyota Production Systems Laboratory to demonstrate the engineering concepts of assembly lines, cycle times, productivity, utilization, throughput, learning curves, bottlenecks, and random variation of data.

Two of the manufacturing activities are Line Balancing and Cycle Time. Both of these activities are centered on assembling skateboards, which provides students with a product that they are familiar with and many enjoy using. An assembly line is setup with work tasks assigned to each of between 4 and 8 stations. The students are assigned to either perform a portion of the assembly at one of the stations, or to collect time study data. They are trained in the assembly method, and then the students run the line for a set period of time. Their productivity as a team is calculated. The data collected at each workstation is discussed – averages of the cycle times, amount of variation, learning curve impacts, effects of the process design versus the person doing the task, etc. Then improvement ideas are discussed, agreements are made regarding which ideas to implement in the next trial, and the line is rerun for the same period of time with the students switching their roles. The difference between the two activities is that for Cycle Time the changes that are explored are more at the detailed level (e.g. parts placement, methods, training, hand motions), while the Line Balancing activity focuses more on systems-level changes (e.g. reassigning work from a busy workstation to a less busy station, adding or subtracting people).

When this activity is run in the lab, it is a very interactive experience for the students. To approximate that experience for the online version of the Line Balancing and Cycle Time activities, a computer simulation of the assembly line was developed (see Figure 2). The actual assembly process was videotaped and a narrated video posted on the REMS website; in addition, narrated videos of the simulation runs were posted as well. The simulation videos include pertinent metrics such as worker utilization and cycle times. Scenarios were chosen for each of the two activities so that a teacher in a classroom could conduct a discussion such as, “we just watched the assembly line run and perform at a certain level, what could be changed to make it run better?” The students in the classroom could have a discussion, examine if their ideas match the scenarios that were developed and posted online, and then see how a subsequent run of the line under different conditions compares to the initial run in terms of the key performance metrics.

In the two activities described in this section (depending on the grade level of the students), classroom concepts that can be reinforced include calculating averages, examining the variability of a data set (e.g. standard deviation), calculating percent improvement, converting pieces

produced to a rate, using a bar chart to visualize different workstation utilizations, understanding units of measure, converting time data to costs, linear equations, and others.

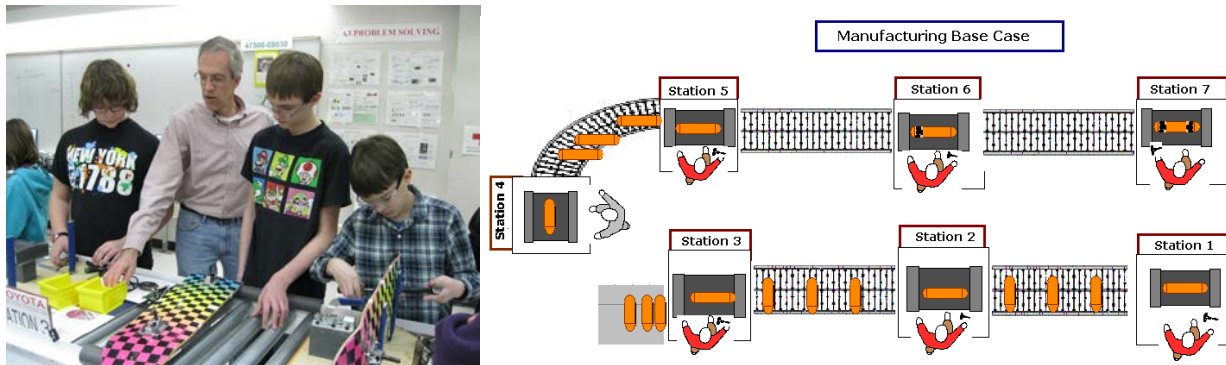


Figure 2. Skateboard assembly activities: (a) student assembling skateboards during an in-lab activity; and (b) simulation example used in the on-line activity.

4.2 Ergonomic Design Activity

The Ergonomic Design activity centers about the design of a manufacturing workstation. The objective of the fifty-minute module is to demonstrate the importance of considering the human user when designing the physical space in which individuals work. Two important concepts that were the emphasis of this module are *ergonomics*, which is the principle of designing systems that are within the physical capabilities of human users, and *anthropometry*, which is the study of the size and shape of people. Prior to the hands-on portion of the module, a brief presentation is given to introduce students to these two concepts, and the facilitator leads a discussion on what scenarios students have encountered in which the physical demands of the system exceeded the physical capability of the student. Common examples that are brought up during this discussion include reaching for a cupboard that is too high or opening a jar with a lid that is too tightly fastened.

In both the in-lab and online versions of this module, students interact with a physical system that intentionally lacks compatibility with the physical size of the students. For the in-lab activity, students perform a simple assembly task that requires them to reach for and gather parts from bins that are located too far away (Figure 3). For the online activity, teachers gather chairs of varying heights (e.g., chairs for elementary students and chairs for adults) or adjustable chairs adjusted in the extreme high or low position, and students sit in each chair to experience the effects of a chair that is too high (dangling feet) or too low (raised knees, poorly distributed seat support).

Having experienced the discomfort or inconvenience of a system that is poorly designed with respect to the bodily dimensions of the target audience, students are then led through a discussion on what the critical dimensions are for the system design (reach distances, lower leg length, etc.) and what corresponding anthropometric measurements are needed in order to make informed decisions about proper design (arm reach, seat pan height, etc.). Students then work in small groups to perform an anthropometric survey to collect data of the bodily dimensions of the group

of students. This is a very hands-on activity that exposes students to the variables that affect data collection of linear measurements (precision, measurement error, etc.). Once data are compiled, students summarize the data in a manner appropriate for the students' level of math. Students then compare the summarized data to the dimensions of the system and draw conclusions about the extent to which the system "fits" the students. The students generally conclude that the system poorly accommodates the class, and discussion ensues about what changes would need to be made to make the system more compatible with the student users. To conclude the activity, students make adjustments to the physical dimension of the system in order to improve how the system fits the students. Students then repeat the assembly operation (in lab) or adjust their chair (online) to the ideal height in order to experience and contrast the benefit of a well-designed system.

In this activity, some of the curricular subjects utilized include ordering rational numbers, measures of central tendency, box-and-whiskers plots, standard deviation, and the normal distribution. Again, various levels of presentation and analysis of the curricular subjects are provided to be grade-level appropriate.



Figure 3: Example of workstation setup before redesign.

5. Assessment

Student and educator surveys were developed, and feedback obtained, to assess both the on-site and on-line activities. The questions were aimed at evaluating whether the students liked the activity, how the activity impacted their understanding of math and science and STEM applications, and how their curiosity in STEM was impacted. An example of the complete survey is shown in Figure 4 and includes the following statements to which students responded:

1. Activity was interesting and fun.
2. Activity increased my understanding of how math/science is used to solve real-world engineering problems.
3. Activity showed a connection to math/science classes.
4. Activity will motivate me to be more interested in my math and science courses.

<p>Relevant Education in Math & Science Program Student Activity Questionnaire</p> <p>Date: _____</p> <p>Gender: Male Female</p> <p>Ethnicity (Circle one): Asian African American Hispanic Caucasian (White) Other</p>	<p>Skateboard Assembly - Cycle Time</p> <p>Grade in School: _____</p>										
Mark an "X" for each question											
Questions	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%; text-align: center; font-weight: bold;">Strongly Agree</td> <td style="width: 15%; text-align: center; font-weight: bold;">Agree</td> <td style="width: 15%; text-align: center; font-weight: bold;">Neutral</td> <td style="width: 15%; text-align: center; font-weight: bold;">Disagree</td> <td style="width: 15%; text-align: center; font-weight: bold;">Strongly Disagree</td> </tr> <tr> <td style="text-align: center;"></td> <td style="text-align: center;"></td> <td style="text-align: center;"></td> <td style="text-align: center;"></td> <td style="text-align: center;"></td> </tr> </table>	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree					
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree							
This Activity...											
was interesting and fun.											
increased my understanding of how math/science is used to solve real-world engineering problems.											
showed a connection to my math/science classes.											
will motivate me to be more interested in my math and science courses.											
Additional Comments:											

Figure 4. Example of student activity questionnaire used for assessment.

Figure 5 summarizes the results of the surveys that were administered to students who participated in the activities. The figures present a weighted average of the percentage of students who “agreed” or “strongly agreed” with each of the four questions. For the in-lab activities, a total of 644 surveys were completed (163 elementary, 426 middle school, 55 high school) across all nine activities. For the online activities, a total of 698 surveys were completed (121 elementary, 539 middle school, 38 high school).

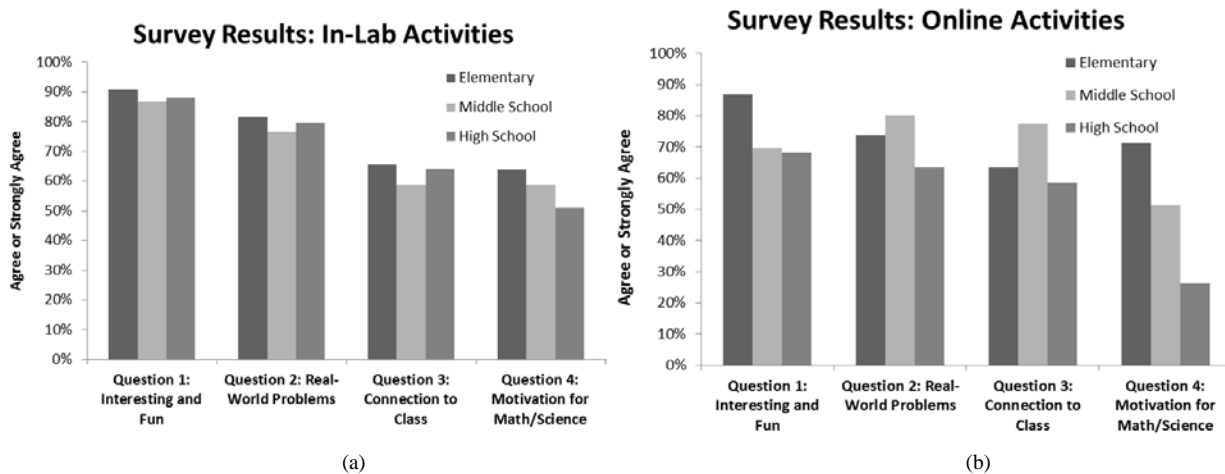


Figure 5: Percentage of respondents who “agree” or “strongly agree” with each survey question for in-lab (a) and online (b) activities. Responses are a weighted average across all nine activities.

For both in-lab and online activities, students thought the activities were fun and interesting and increased their understanding of how math/science is used to solve real-world problems. Online activities seemed to do a slightly better job of showing a connection to math/science class, especially for middle school; maybe this was because these sessions were mostly teacher-led as opposed to the in-lab activities which were often conducted by university faculty and graduate students. It would make sense that teachers could better relate what was being covered in class. Scores were lowest for motivating interest in math and science courses, but we contend that a large percentage is lofty goal for a single activity. In that light, numbers in the 50-60% range are quite good, in our opinion.

Assessment and evaluation of all of the in-lab and online activities informed continuous improvement throughout the life of the project. Student comments as well as educator comments were also captured that assisted in driving continuous improvement. All of this data was evaluated throughout the development process, and improvements were made. Table 2 shows an example of the continuous improvement aspect of this project. The “Initial” column in the table shows the feedback we received from two groups of students who completed one of our activities shortly after the completion of the testing phase. We were not pleased that the percent of students who responded with “Agree” or “Strongly Agree” to the statements on the “Student Activity Questionnaire” was so low. So we made some design changes to the activity, and implemented the changes. The most common changes made across all activities involved engaging the participants more and reducing the amount of time the facilitator spent talking. Improvement to the activities is also confounded by the improvement that naturally occurs through repeated performance. The 2nd column titled “Improved” shows the results from two different groups of students who experienced the same activity in the lab four months after the first group. The improvement to the scores was significant.

Table 2. Example of continuous improvement supported by assessment data.

<i>Evaluation of the in-lab Meal Picking Activity student assessments during initial activity implementation, 7/9-10/2013 sessions, compared to improved activity after several In-Lab activities were conducted. Improved results shown for sessions conducted 11/6-20/2013.</i>				
Assessment Question	Meal Picking Activity			
	% Students Who Strongly Agreed or Agreed			
This activity...	INITIAL		IMPROVED	
	DATE RANGE: 7/9 - 7/10	# Sessions: 2	DATE RANGE: 11/6 - 11/20	# Sessions: 2
	N	%	N	%
Question 1: was interesting and fun.	24	79%	23	91%
Question 2: increased my understanding of how math/science is used to solve real-world engineering problems.	24	54%	23	87%
Question 3: showed a connection to math/science classes.	24	35%	23	83%
Question 4: will motivate me to be more interested in my math and science courses.	24	38%	23	78%

6. Conclusions and Future Work

Though the development of the REMS outreach program we have been able to create an effective math and science curriculum activities for grades 5–12 with a hands-on industrial engineering focus. This outreach program uses age-appropriate teaching activities linking math and science to real-world industrial engineering challenges. Through the deployment of the activities we have been able to reach out to many students and expose them to STEM applications. Furthermore, the REMS program provides a model for outreach programs for students who have access to fun, age-appropriate hands-on activities that link math and science to real world industrial engineering problems.

In terms of future work, we plan to continue to work with our university K-12 outreach group as we continue to receive requests from schools and other groups that educate and / or provide STEM related activities for students. We will continue to use the surveys that are in place to collect feedback from the participants and their adult guides / sponsors, and utilize the feedback to make modifications and to continuously improve the program.

7. Acknowledgements

The development of the REMS program was made possible through a grant from the Toyota USA Foundation. In addition to the authors of this paper, significant contributions to the REMS program have been provided by the following individuals: Dr. Andres Carrano, Tina Bonfiglio, Arlene Meyer, Karen Ester, Rami Abuabara, Abbey Donner, Atul Ghadge, Elizabeth Khol, Sourabh Jain, Catina Jelfo, Jennifer Leone, Christian Lopez, Sean Murnan, Kaitlin Peranski, Tim Schmoke, Ajith Sharma, Manuel Sosa, Srinath Sriram, Kshitij Luthria, Clayton Tontarski, Jeff Wojtusik, and Fatma (Selin) Yanikara. Finally, we acknowledge the support provided by the Women in Engineering (WE@RIT) program, the Toyota Production System Laboratory, and the Industrial and Systems Engineering Department at RIT.

References

- [1] Reeping, D., & Reid, K. (2014). Student Perceptions of Engineering after a K-12 Outreach--a" STEM Academy. In, *Proceedings of the 2014 ASEE North Central Section Conference*, American Society for Engineering Education.
- [2] Innes, T., Johnson, A. M., Bishop, K. L., Harvey, J., & Reisslein, M. (2012). The Arizona Science Lab (ASL): Fieldtrip based STEM outreach with a full engineering design, build, and test cycle. *Global Journal of Engineering Education*, 14(3), 225-232.
- [3] Moskal, B. M., & Skokan, C. K. (2011). Supporting the K-12 classroom through university outreach. *Journal of Higher Education Outreach and Engagement*, 15(1), 53-75.
- [4] TEACH Engineering, Available on-line via <https://www.teachengineering.org/> .
- [5] Try Engineering, Available on-line via <http://tryengineering.org/> .
- [6] Design Squad Nation, Available on-line via <http://pbskids.org/designsquad/> .