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Increasing STEM Understanding and Engagement Through Engineering Learning Activities

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Engineering education encourages students to apply disciplinary concepts and use technology to solve real-world problems (Moore et al., 2014). Engineering problem-solving activities can help students see connections between engineering and other disciplines, but only if educators teach with the intent to improve students' understanding of the underlying science and math concepts (Dixon & Brown, 2012). Scholars (Honey, Pearson, & Schweingruber, 2014) have called for research investigating how science and math concepts can be taught within the context of engineering projects. The purpose of this design-based research was to investigate the underlying science and math concepts embedded in middle school activity-based engineering lessons and to enhance selected lessons to promote the understanding and application of science and math concepts.

This research focused on identifying and redesigning engineering activities appropriate for a middle school audience, students in grades 6 through 9. In the first phase of the study, six activity-based engineering lessons representing a range of engineering and computer science disciplines were redesigned to include a "Minds-on" introduction to the science and math concepts, a "Hands-on" problem-solving task, and a "Thoughts-out" discussion of concepts and applications. Each lesson featured a real-world problem that Charlie the Charger, the University of New Haven mascot, assigned. These problems were especially relevant for middle school students:

- Charlie needs to power his LED bulb with the fruits and vegetables he brought to camp.
- Charlie has encrypted information to share with his friends and they need to decrypt the message.
- Charlie dropped his toy cars and he needs to create some replacement parts.
- Charlie needs a boat to sail at the park near his house.
- Charlie moved into a new home and needs help designing a table for his room.
- Charlie is out camping and needs to make a water filter to purify water.

In the second phase of the study, the lessons were distributed to teachers who participated in Project Lead the Way (PLTW), a nationally recognized program that prepares science and math teachers to teach engineering in their schools. These expert teachers were invited to provide input on the lesson design and to identify the underlying science and math concepts and engineering applications. Results from the survey yielded evaluations of 5 lessons. To increase the response rate, the survey will be re-administered during the school year. The survey results were analyzed to determine the underlying science and math concepts and the engineering applications identified by the expert teachers. Table 1 shows these results.

Table 1

Examples of Concepts, Connections, and Applications in Activity-based Engineering Lessons

Lesson Title and Topic	Concepts	Subject Area Connections	Engineering/ Computer Science Applications
Charlie's Hidden Messages Caesar Cipher	Patterns, cryptography, coding, encryption	Mathematics (logic), biology (DNA code), English language arts, communication	Computer science, cyber security
Fruit Power Alternative Battery	Electricity, circuits, energy sources	Chemistry, physics, general science	Chemical and electrical engineering
Charlie Needs a Boat! Buoyancy	Density, balancing of forces, weight, engineering design	Physics, general science, mathematics	Mechanical and marine engineering
Racing Cars Interchangeable Parts	Measurement, tolerance, fit, dimensions	General science, geometry (composite figures), mathematics	Civil, mechanical, and industrial engineering
Charlie Needs a Table! Structures	Scaling, force, stress, quantitative reasoning	Physics, algebra, geometry	Civil and architectural engineering
Charlie's Water Filter Water Filtration	Water cycle, percolation, sedimentation	Environmental science, general science, chemistry	Civil, environmental, chemical, and materials engineering

Note Preliminary results based on analysis of the lesson plans and expert teacher surveys

After survey results were analyzed, the researcher used the expert teachers' input to revise the lessons. The "hands-on" activities were also tested in a "lab" setting to determine how students might use the lesson materials to solve the engineering problems. Activity directions and materials were refined accordingly.

In future research, the revised lessons will be piloted with middle school students. Pre and post tests will be developed and administered to assess students' knowledge of the target concepts before and after participating in the activity-based engineering lessons. Students' interest in engineering careers will also be assessed because one important long-range goal is educational outreach. The expectation is that these activity-based lessons will introduce middle school students to different engineering disciplines and the underlying science and math concepts

that engineers apply to solve real world problems, and ultimately encourage these young students to pursue careers in engineering and applied sciences.

References

Dixon, R. A., & Brown, R. A. (2012). Transfer of Learning: Connecting Concepts during Problem Solving. *Journal of Technology Education*, *24*(1), 2-17.

Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM *Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18612.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In *Engineering in pre-college settings: Synthesizing research, policy, and practices (*pp. 35-60). Purdue University Press.