ASEE'S VIRTUAL CONFERENCE
At Home with Engineering Education
JUNE 22 - 26, 2020 #ASEEVC
Paper ID #31376

Using Computer-Generated Concept Maps in the Engineering Design Process to Improve Physics Learning

Mr. Michael S Rugh, Texas A&M University

Michael S Rugh is a third year PhD student focusing on mathematics education within the Curriculum and Instruction PhD track in the Department of Teaching, Learning, and Culture within the College of Education and Human Development at Texas A&M University. His current focus is on informal STEM education. Within this, he has taught for the past two years at ASSC, the Aggie STEM Summer Camp. He has over 16 presentations and publications and is constantly working on more. He has taught integrated math and science, elementary math methods, and problem solving in math at Texas A&M University. He is currently serving on several review boards and is Assistant Editor for the Journal of Urban Mathematics Education.

Mr. Donald Joseph Beyette, Texas A&M University

Donald Beyette is a master with thesis student at Texas A&M University studying abstractive summarization, Q/A models, ontology, and engineering education. Current research areas are focusing on systems to model a users learning behavior with DIME.

Dr. Mary Margaret Capraro,

Dr. Mary Margaret Capraro is a Professor of Mathematics Education in the Department of Teaching, Learning and Culture and Co-Director of Aggie STEM. She received her Ph.D. from the University of Southern Mississippi and joined Texas A & M University in 2000 as a clinical professor in Mathematics Education. She earned a position as an Assistant Professor in 2007 and was promoted to Full Professor in 2016. Her research interests include student understanding of mathematical concepts especially in the area of problem solving and problem posing. She was previously employed with the Miami Dade County Schools as both a teacher and an assistant principal. She has over 100 peer-reviewed articles, and 175 national and international presentations.

Dr. Robert M Capraro, Texas A&M University

Robert M. Capraro, is Co-Director of Aggie STEM, Director of STEM Collaborative for Teacher Professional Learning, and Professor Mathematics Education in the Department of Teaching Learning and Culture at Texas A&M University. Dr. Capraro's expertise is applied research in school settings, program evaluation, the teacher as change agent for STEM school improvement, and STEM student achievement. He recently received the best paper award from the International Conference on Engineering Education where he and two colleagues presented their work related to the Aggie STEM project. He is currently involved in research in four school districts and more than 20,000 students and 80 teachers. His editorial work includes Associate Editor of the American Educational Research Journal, School Science and Mathematics, and Middle Grades Research Journal and the Research Advisory Committee for the Association of Middle Level Education. He was selected as a minority scholar for 2007 by the Educational Testing Service and served as president of the Southwest Educational Research Association. He is the author or co-author of three books, several book chapters and more than 100 articles on mathematics education, quantitative research methods, and teacher education published in such venues as Journal of Mathematics Education, International Journal for Studies in Mathematics Education, Journal of STEM Education: Innovations and Research, International Journal of University Teaching and Faculty Development, LEARNing Landscapes, Special Issue: Mind, Brain and Education, Journal of Mathematical Behavior, European Journal of Psychology of Education, The Journal of Mathematical Sciences and Mathematics Education, Urban Review, Journal of Urban Mathematics Education, Educational Researcher, Cognition and Instruction, Educational and Psychological Measurement. He recently was awarded a $400,000 dollar grant - - continued support by the Texas Higher Education Coordinating Board to continue his work with developmental education bringing his total external funding to ˜31 million.

Using Computer-Generated Concept Maps in the Engineering Design Process to Improve Physics Learning

(Resource Exchange)

Michael S. Rugh*†, Donald J. Beyette‡, Mary Margaret Capraro*†, & Robert M. Capraro*†

*Aggie STEM; †Department of Teaching, Learning and Culture; and ‡Department of Computer Science and Engineering

Texas A&M University

Purpose

Students engage in the *Engineering Design Process* and explore the relationships between concepts involved in simple rotational motion using automatically generated *Dynamic and Interactive Mathematical Expressions (DIME) maps*. Provided with DIME maps while researching and exploring concepts, students can visualize the connections between concepts and better understand how the physics concepts affects the design of their spinning objects.

Overview

Through designing and building spinning objects, students anchor their learning in tangible design-based experiences. They are tasked with building a spinning object that either spins fastest or spins longest. With these goals in mind, teachers can guide students to research concepts including angular velocity, moment of inertia, and angular momentum. During this research time, students can make full use of the provided DIME map.

A detailed suggested day-by-day outline can be found at tx.ag/DIMEmaps

Recommended Materials*

This section contains a list of recommended materials for the activity. More craft materials can be supplied as desired.

- Skateboard Bearings, at least 1 per student
- Popsicle sticks
- Cable ties
- Silicone Lubricant
- Hot glue guns and sticks
- Super glue
- Duct Tape
- Weights. Examples include:
  - Pennies, about 250 per 10 students
  - Magnets
  - Washers and hex nuts

*A detailed expansion of references, materials, and the activity in practice, visit http://tx.ag/DIMEmaps

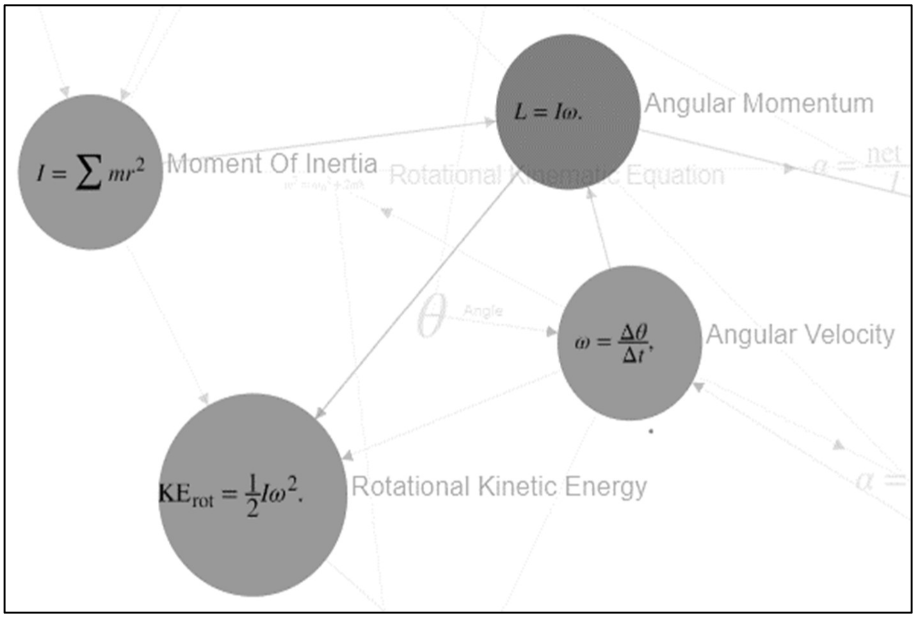
This activity encourages creativity and multiple designs

Target Grade Level

This activity has been tested over three years, from 2017 to 2019, with 7th through 12th grade students. For students who may have not encountered degrees or radians in their coursework, additional instruction may be required.

Why engage students in Engineering Design?

- Cultivates 21st century skills such as problem-solving and creativity (Bicer, et al., 2019; Morgan, Moon, & Barroso, 2013),
- Leads to efficient solutions (Morgan, Moon, & Barroso, 2013),
- Provides realistic contexts for the application of math and science (Daugherty, 2012; Morgan, Moon, & Barroso, 2013),
- Develops stronger interest in STEM (Bicer & Lee, 2019; Morgan, Moon, & Barroso, 2013)
- Increases social and environmental awareness (Akleman, et al., 2019)



Why does Earth keep on spinning? What started it spinning to begin with? And how does an ice skater manage to spin faster and faster simply by pulling her arms in? Why does she not have to exert a torque to spin faster? Questions like these have answers based in angular momentum, the rotational analog to linear momentum.

By now the pattern is clear—every rotational phenomenon has a direct translational analog. It seems quite reasonable, then, to define **angular momentum** L as

$$L = I\omega. \quad (10.90)$$

This equation is an analog to the definition of linear momentum as $p = mv$. Units for linear momentum are $kg \cdot m/s$ while

Part of a DIME map and displayed textbook text

Contact Info

If you would like to be contacted with additional information about how to use DIME maps in your classroom, send an email to Michael.Rugh@tamu.edu

Additional Links and Resources

For a detailed example of this activity in practice, visit http://tx.ag/DIMEmaps

References

Akleman, E., Barroso, L., Capraro, M. M., Creasy, T., Fleming, K., He, W., . . . Williams, A. M. (2019). Recycling plastics: Middle school students create solutions during a summer camp. European *Journal of STEM Education*, *4*(1).

Bicer, A., Lee, Y., Capraro, R. M., Capraro, M. M., Barroso, L. R., & Rugh, M. S. (2019). Examining the effects of STEM PBL on students' divergent thinking attitudes related to creative problem solving. *In Proceedings of the 49th annual IEEE Frontiers in Education (FIE) Conference.*

Daugherty, J. L. (2012). Infusing engineering concepts: Teaching engineering design. *National Center for Engineering and Technology Education.*

Morgan, J. R., Moon, A. M., & Barroso, L. R. (2013). Engineering better projects. In R. M. Capraro, M. M. Capraro, & J. R. Morgan (Eds.), *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach* (2nd ed., pp. 29-39). Rotterdam, The Netherlands: Sense. Publishers.

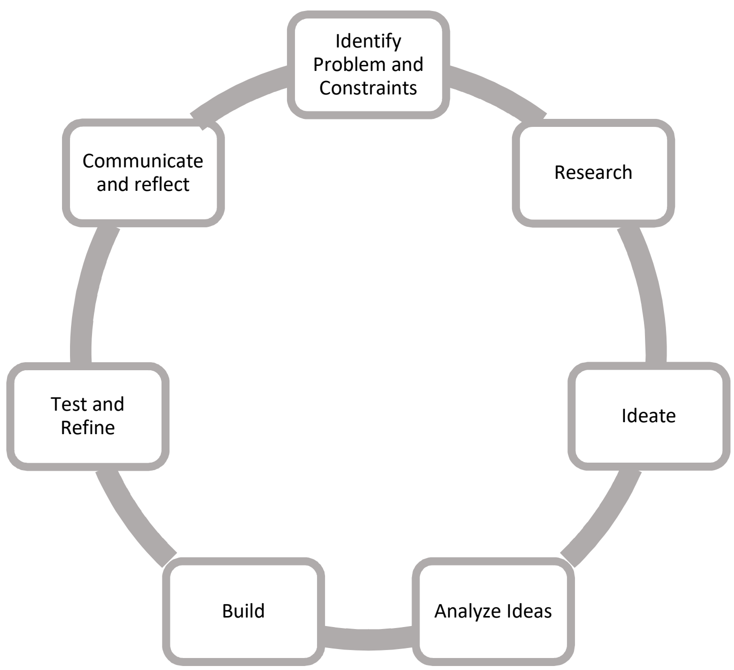
The DIME Map

Through a collaborative effort between the College of Education and the College of Engineering, we have created a learning technology that can assist students in the self-guided research and ideate phases of the engineering design process. A Dynamic and Interactive Mathematical Expressions (DIME) map is an automatically generated map of the connections between mathematical equations, expressions, and variables (aka mathematical objects) found in a chosen PDF document (Beyette et al., 2019; Rugh et al., 2019). The user, generally a teacher or researcher, begins by uploading a PDF file of a desired textbook chapter to the DIME Map system, a machine-learning program that employs natural language processing methods to identify and define mathematical objects. The identified mathematical objects are then connected based on a set of logic rules and the resulting map is given to students as a resource to enhance learning (see Figure 2).

As a self-guided learning tool, DIME maps are perfectly situated to assist in learning, especially when students are exploring knowledge at their own pace. This resource provides the organization of a week-long STEM PBL based on engineering design principles which utilizes DIME maps to improve students' learning.

Acknowledgements

Thanks to Drs. Luciana Barroso, Mary Margaret Capraro, Robert M. Capraro, and the Aggie STEM team for the opportunity to work with the Aggie STEM summer camp students. Visit them at AggieSTEM.tamu.edu



Seven-step engineering design process
(Morgan, Moon, & Barroso, 2013)