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26

Mechanical Engineering Education: Preschool to Graduate School

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1. Introduction

Google decided to re-invent television by creating Google TV: which is basically software that can access everything available on regular television channels and the vast sea of content on the Internet, all on the biggest screen in the house. One motivation was to transform their current 1 billion market share associated with computer and hand held browsers to 4 billion TV watchers. When this feat is accomplished, the current statistics that cite 70% of 4 to 6 year olds have used computers and been exposed to the Internet prior to kindergarten will likely increase to 100%. In these exciting times there is a need to integrate this multi-modal influence into engineering education on a massive scale. According to studies, this new generation of Millenials (born early 1980-2000) places significant emphasis on meaningful careers. By introducing impactful, engineering education to this generation by integrating literature, technology, and successful teaching and learning methods into their culture, there are no limits to the meaningful contributions that future engineers will make toward improving our way of life. This chapter will highlight mechanical engineering education from kindergarten to functioning society member. We will discuss what works and how it works with the new student and citizen of today.

2. Early engineering literacy

Engineering education at the youngest ages is largely predicated on hands-on activities using manipulatives such as *LEGOS*™ [1]. But at the young ages of P-2nd grade, there is significant emphasis on language and literacy skills such that little time is devoted to science or engineering education in the classroom [2, 3]. Therefore, integrating engineering concepts into language and literary skills designed for young children could impact the early development of engineering thinking while simultaneously enabling more instruction and exposure to engineering concepts than currently exist. It is important to understand how purposefully prepared engineering literature presented in the format of picture book children's stories impacts learning in emergent readers. The influence of literature on children's thinking about *engineering* and the connection children make between science and engineering can be observed through illustrative data and feedback after exposure to engineering literature [4-8].

By first grade, readers have developed an understanding of the alphabet, phonological awareness, and early phonics [2, 3]. They have command of a significant number of high-frequency words and developing a much better grasp of comprehension strategies and word-attack skills. They can recognize different types of text, particularly fiction and nonfiction, and recognize that reading has a variety of purposes. Typically books for this reading level contain: increasingly more lines of print per page, more complex sentence structure, and less dependency on repetitive pattern and pictures [3]. Examining this developmental reading level will enable a link between how engineering literature is presented and how children process the information[8]. Researchers are currently working to create improved books targeting this specific developmental level. Engineering books available at this developmental level are severely limited.

The idea that engineering learning could be promoted through literature is supported by the theoretical perspectives of situated cognition and distributed cognition [9-14]. Especially from the perspective of a young child, engineering activities can be described as socio-cultural such that a person's cognition is enmeshed with a situation and activity in a community of practice [9]. In other words, *concepts* are formed by both *culture* and *activity*, and the meaningfulness of learning is constrained by all three conditions. In this way, the literature needs to present an engineering concept in the framework of a culture (i.e., characters in a story) ensnarled in an activity (i.e., venturing through the story's plot) [13].

Engineering Elephants [6] is a children's book that introduces the engineering profession as well as fundamental Science, Technology, Engineering, and Mathematics (STEM) concepts to young children. The book teaches children about relevant topics such as nanotechnology, renewable energy, and prosthetics by engaging them through an interactive journey of an elephant and his questioning of the world around him. The authors worked with early childhood literacy experts, science museums, and local school districts to strategically develop the text. The text was composed using the language of engineering (i.e., asking questions) and introduces vocabulary relevant to engineering using a narrative text structure and lyrical pattern children are familiar with as well as vibrant water color artwork that provide context clues and deeper understanding (see Fig. 1)[6].

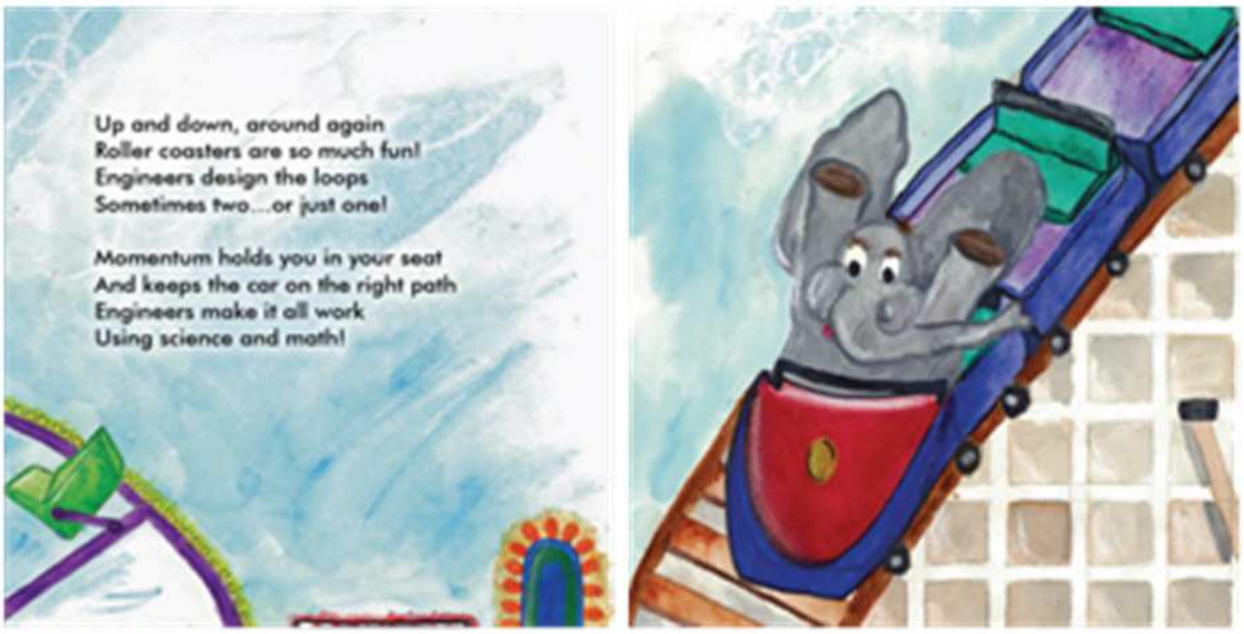

Fig. 1. Excerpts from **Engineering Elephants** that illustrate the interactive, engaging presentation of engineering concepts tailored to young ages.

As an example of current research results in engineering literature, the following study will be discussed. A group of children is examined where half had been exposed to **Engineering Elephants** and the other half had not (the control group). After reading and discussing the story, each classroom engaged in a creative paper-and-pencil activity in which the students were asked to draw what they would design if they were an engineer and explain their picture with corresponding text. This drawing assignment was also given to the classrooms that had not been exposed to **Engineering Elephants**. Figures 2 and 3 show representative illustrations from both groups of students.

Fig. 2. Engineering illustration by student not exposed to Engineering Elephants. Text reads "*Me Driving a Train in the Daytime*".

Science is guided by observations and builds and organizes knowledge in the form of testable explanations and predications about the world [15, 16]. Engineering can be described as part investigative scientist and part creative inventor with the goal of solving practical problems using both math and science. Engineering is not synonymous with science but uniquely distinct yet synergistically entwined with overlapping epistemologies. The key learning objective in this study is teaching children what engineering is and how it is different than science.

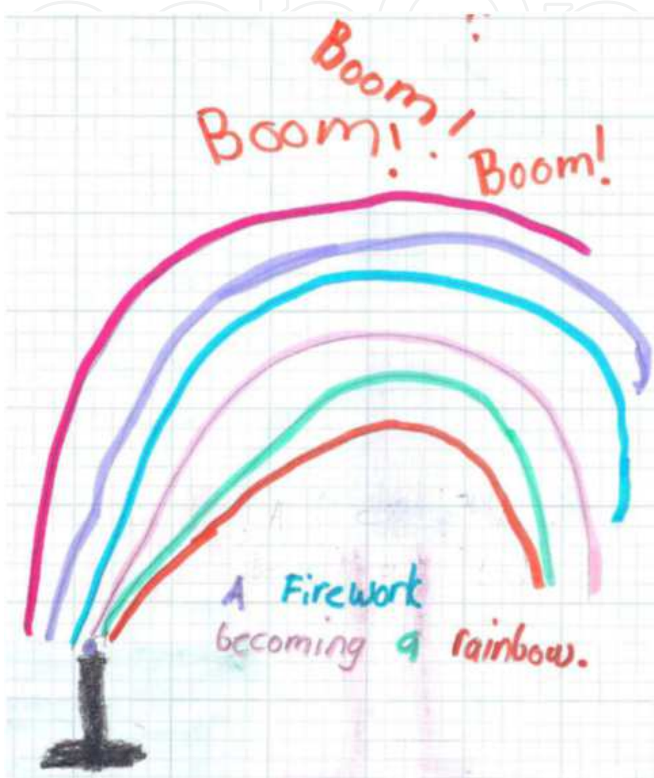

Fig. 3. Engineering illustration by student exposed to Engineering Elephants through class reading and discussion. Text reads "*A firework becoming a rainbow*".

The children's drawings show the advanced ways that they think about ideas [5, 7]. When asked to draw what they would design when they were an engineer, the students did not hesitate to immediately picture themselves in this role. The student who had never been exposed to **Engineering Elephants** or in any type of classroom instruction (Fig. 2) held the common belief that engineers drive trains or work on trains. Several students drew pictures of flowers or clouds and appeared to be unable to make any connection to engineering at all, which is also very typical of this grade level. The students that had read **Engineering Elephants** in class and participated in class discussion about engineering showed elevated knowledge in their drawings with direct correlations to topics covered in the book. For example, Fig. 3 shows a firework becoming a rainbow. **Engineering Elephants** uses fireworks to explain combustion. It is encouraging that the students are obviously learning through this text because their drawings show they have begun to develop concrete ideas about engineering [5].

The purpose behind the development and use of **Engineering Elephants** or children's literature in general is not mastery of all engineering concepts, but to introduce children to the idea of engineering and problem solving and encourage them to begin to imagine all of the things that they could potentially create. Results from integrating Engineering Elephants into 1st grade classrooms show that engineering literature inspires heightened levels of creativity and instilled a concrete sense for what engineers can do. These results show the need for engineering based literature that complements current scientific curriculum such that the stories can more easily be integrated into every classroom and foster early enthusiasm for engineering.

3. Integration of junior – And high-school science clubs and university engineering societies

The Technology Student Association (TSA) is one example of a national non-profit education organization dedicated to promoting engineering and helping students discover their potential for the engineering or technology-based professions [17]. A solid framework of secondary school educators, corporations, professional organizations and universities incorporate pre-college engineering programs in local communities throughout the United States. Another example is the Junior Engineering Technical Society (JETS) which employs a unique and innovative approach—explore, assess, experience—and through which thousands of diverse students are enticed to pursue engineering majors and careers each year [18]. Collegiate student sections of the American Society of Mechanical Engineers (ASME) [19] have worked with local high school professional organizations in an effort to generate future engineering talent. Through this collaboration, TSA or JETS and ASME engages students in a variety of educational programs, increasing awareness of what engineers do and showing how math and science are used to make tangible differences in the world. Students participate together in local, regional, and national engineering competitions, conduct local service projects together, and participate in several social events structured to make connections and build friendships between the students. Foundations for student impact are built upon providing career resources and experiences not often found in traditional learning environments; opening students' minds to their own career possibilities by removing social barriers and negative attitudes about engineering; and addressing major industry needs for a qualified, engineering-literate workforce. These collaborations also provide unique mentor/mentee relationships between high school students and undergraduate engineering majors that can provide the support needed for college transition.

4. Mentoring

"I am here today because I had (chose one of the following): teacher, counselor, mentor in the community, college professor, principal, who believed in me and opened their (chose one of the following): classroom after school or during lunch, research lab, workplace to me and let me see the real world of learning and science beyond the classroom."[20] Mentoring is quite simply an older student, teacher, or professional taking an interest in the life and aspirations of a younger protégé. More formally Kram defines mentoring as a relationship between an experienced individual and an understudy where the experienced individual acts as a role model, providing support and direction[21]. The quote above paraphrases the comments of successful graduates from the Academy for Math, Engineering, and Science, AMES, a Title One science, technology, engineering, and mathematics (STEM) early college high school in Salt Lake City. The graduates of this program when speaking of college and professional success indicate the common theme of a mentor making a difference in their lives. AMES program leadership indicates that it is the forging of relationships that holds the key to increasing diversity in the STEM fields. Student-Professional and Student-Student are two common types of mentoring programs used in engineering education. Examples of these programs and the qualities that define their success are described below.

The ACE (Architecture, Construction, and Engineering) Mentoring Program of America began in 2002 with the goal of introducing high school students to the construction industry and encouraging students to pursue careers in building and design. The ACE program operates as a twice per week after school program that pairs interested students with a volunteer professional in the field of architecture, engineering or construction. Students and mentors work in teams that mimic the construction process. A 2009 survey administered to past ACE student participants found that 94% had immediately entered college upon graduation from high school, far above the national average of 73%. Sixty-six percent of respondents indicated they were pursuing or considering the pursuit of a career in architecture, engineering or construction. The ACE program is viewed as one potentially effective model for recruiting youth into the STEM disciplines[22, 23].

Peer Led Team Learning (PLTL) is a successful undergraduate student-student mentoring and instructional strategy that was originated in Chemistry at City College of New York in 1991. It has rapidly spread across the country and STEM disciplines, including engineering. In PLTL, previously successful students in a particular STEM course are recruited to be peer leaders, and each leader is assigned a small group of six to ten students currently enrolled in the course. This team of students and team mentor meet weekly engaging in problem solving and discussions of course content. The PLTL program in a science, mathematics or engineering course requires a portion of lecture time be replaced with a laboratory PLTL period. Mandatory attendance is recommended. A growing body of research supports the utilization of PLTL with students participating in PLTL consistently outperforming those who did not by a third of a grade point with similar student groups [24, 25]. At institutions where PLTL was implemented across the curriculum, student pass rates were seen to increase in General Chemistry by 15% while retaining the level of rigor prevalent in a standard lecture course [26]. PTLT was applied to a first year electrical and computer engineering course and found regular attendees to PTLT sessions performed better on the final examination despite exhibiting lower entering ACT and SAT scores [27]. The mentoring relationship developed in PLTL has been shown to have positive impacts on the peer leaders as well. The Learning Assistance program at the University of Colorado Boulder has seen a consistent increase in the number of students choosing to enter the secondary education field after serving as a peer leader [28]. The Peer Led Team Learning website, www.pltl.org is an excellent resource for those desiring to initiate a PTLT program. The website provides guidance on content for PTLT sessions for all STEM courses as well as training for team leaders [29].

Another effective model for mentoring is the implementation of a research experience and transitional program to graduate school for engineering students. In particular, the goal of this program is to provide research experiences for graduate students while providing positive role models for undergraduate engineering students and introduce them to research and applied engineering work in a supportive atmosphere. A program like this was initiated in the Mechanical Engineering Department at Texas Tech University (TTU) in 2001 with a small group of mentoring teams. Initially this program targeted only women and underrepresented groups in an effort to encourage them to consider graduate school. This mentorship program was highly successful in that more than 50 % of the undergraduate participants went on to earn a graduate degree. Many programs of this type recruit underrepresented students by sending them personalized invitations to participate but will also include participation from all students. A successful transitional program was implemented at West Texas A&M University (WTAMU) in 2009. WTAMU currently does not have a graduate program in engineering and TTU is the closest graduate program in mechanical engineering (e.g. roughly 75 miles). This is a unique opportunity for students at WTAMU to be involved in research and get some exposure to graduate school. The goals of the transitional program are to:

1. Enrich both the mentor and mentee's educational experience by enhancing their understanding of engineering, while fostering a collaborative learning environment; and
2. Recruit undergraduate students to pursue a graduate engineering degree.

These goals are accomplished through the mentoring of an undergraduate engineering student (at WTAMU) by a graduate engineering student (at TTU) with similar interests. The students earn credit for working on well-defined research projects in nanoenergetic materials. Feedback from the pilot program indicates that working together on a research project allows the students to form a solid and comfortable mentoring relationship. This project-oriented approach to mentoring exposes undergraduate students to a graduate engineering program and research in a non-threatening and approachable manner.

This transitional program commences with a graduate student training seminar. This seminar prepares the graduate student mentors for their role in the program. As a mentor, a graduate student has much to offer an undergraduate who is interested in engineering research such as encouragement, guidance, and support. In various studies across fields, being mentored has consistently been linked with academic and professional achievement [2-5]. WTAMU undergraduates also receive numerous benefits from the transitional program. They gain an increased understanding of a graduate research, receive guidance and advice, develop higher confidence levels, and gain access to networks and other resources in the mechanical engineering department at TTU. The graduate students also benefit through a self-reflection about their own academic path, and they report gaining an increased understanding of their discipline and develop supervisory and management skills.

5. Problem-based learning in undergraduate engineering education

Problem-based learning (PBL) was first introduced in medical education in the late 1960s. By the early 1970s it has spread to medical institutions worldwide. In a pure PBL setting, groups of students are first presented with discipline relevant problem, not unlike a problem students would encounter in the profession. No facts or theories are presented, but rather students "brainstorm" regarding the important aspects of the problem and develop learning objectives they feel are necessary for its solution. The instructor or student facilitator may direct the conversation so that the students are focusing on the important aspects of the problem. Based on the objectives determined each member of the group is assigned a task. Students then reconvene to share the obtained information, determine if additional information is needed, and this process continues until a solution is obtained[30]. The positive impacts of PBL are the development of problem solving skills as well as an independent learning approach to solving a problem. PBL mimics the situations that are presented to students once they enter a profession. In its purest form, PBL is not without controversy. Some studies have shown no difference and sometimes lower content knowledge scores for PBL students. Students exhibit gaps in their knowledge base created by PBL activities that do not cover all the required course content[31, 32]. PBL has not gained significant popularity in engineering due to concerns over content knowledge gaps as well as the large time scale necessary to solve a significant engineering problem[33]. PBL can be successfully integrated into a traditional engineering curriculum, creating opportunities for students to develop the crucial interdisciplinary problem solving skills necessary in engineering.

Research indicates the application of the foundation disciplines of mathematics and physics into practical engineering application problems increases student engagement [30, 34-36]. Embedded in all significant engineering problems are smaller scale mathematics and physics problems. These mathematics and physics problems could be viewed as part of a more complex engineering problem and individually require a much smaller time commitment than the engineering problem as a whole. A logical solution to the issue of time commitment in a single course is a linked class approach. An engineering problem is introduced to students enrolled in Engineering Statics, Physics, and Calculus II. Students in all three courses discuss the problem and isolate the imbedded mathematics, physics, and engineering problems. The three smaller problems are then solved concurrently by students in the relevant course. The interdisciplinary nature of this strategy allowed students in all three courses to see the application of their knowledge of calculus and physics to a significant engineering problem. A linked class PBL project can easily be utilized in a curricular learning community setting; however, it is not required. If the PBL project is built upon core courses in the engineering curriculum, then students who are not dual enrolled in two or more courses benefit from the experience and application of previous course content. Examples of PBL projects used to link engineering and mathematics courses can be found in [37, 38].

Key to the success of a linked-class PBL experience is planning and coordination between the course instructors. Scheduling of all courses is critical if the project is to be given to the students simultaneously and prior to coverage of the necessary conceptual knowledge. A goal with a linked-class PBL experience is that students first devise a hypothesis based on their previous knowledge and then adapt their method of solution when new knowledge is obtained.

Further research is needed on how to assess the impact of PBL experiences on student learning. A primary focus of PBL is teaching a student to be a self-learner. This is a difficult goal to assess. However, with the additional goal of increased student engagement, the collection of survey data regarding student impressions of the experience and of their learning gains is an important assessment of the program. The Student Assessment of Learning Gains (SALG) website, www.salgsite.org, is supported by the National Science Foundation and is a valuable resource for institutions desiring to develop surveys instruments that address the student perspective of a learning experience[39]. This survey is an excellent choice when desiring that students reflect on their learning experience. This survey also provides an excellent source for student feedback. Creating a successful PBL experience requires a certain amount of “trial and error” approach and it improves with implementation. Student feedback provided by this type of survey is particularly helpful for improving the experience for each new group of students.

Traditional forms of assessment in the content areas of the PBL experience are also important considering the concerns regarding content gaps in student knowledge with PBL implementation in medical education. Embedded assessment questions on common course final examinations are an excellent means of comparing student content knowledge for students involved in PBL experiences with those who were not.

Students understand and better retain information when it is provided in the framework of a problem where it is seen to be relevant. PBL experiences by definition provide this educational setting while also developing students learning and problem solving skills. Due to the potential for positive impacts on student learning, it is important that way are found to implement this strategy into the engineering curriculum.

6. Learning communities in undergraduate engineering curricula

Learning communities have been implemented across the country in a variety of disciplines and first-year experience programs as a means of increasing retention of first-year students. Learning communities have varying forms, however Lenning and Ebbers [40] have identified 4 common types (1) curricular learning communities that enroll a cohort of students in two or more common paired or clustered courses; (2) classroom learning communities where a cohort of students enrolled in a large lecture are broken into smaller cohorts for cooperative learning and group process learning opportunities (3) residential living and learning communities where students with a common major live in the same area of a residential hall increasing the opportunity for out-of-class learning experiences; (4) student type learning communities which enroll a targeted group, for example academically at risk students, honors students or minorities in engineering.

Several published studies have linked curricular learning communities to increased retention of first-year students, higher first year GPAs, and lower incidence of academic probation. [41-43] While living and learning residential hall programs are fairly common in engineering programs across the country, curricular learning communities are rare in the engineering curriculum. [44] Zhao and Kuh [45] indicate the simple cluster enrollment model of a cohort of students co-enrolled in two or more courses is improved upon when the faculty involved in these courses design activities that require the application of topics from all clustered courses. This curriculum integrated approach to learning communities promotes the development of critical thinking skills and an interdisciplinary approach to problem solution. Learning communities with integrated curriculum have the potential to significantly impact first year retention of students in engineering by

1. creating an opportunities for students to form lasting study groups early in their academic career;
2. emphasizing the importance of the fundamental disciplines of mathematics and the sciences in the engineering problem solving process within the first year;
3. increasing critical thinking and engineering problem solving skills by integrating the foundation disciplines of mathematics and the sciences into practical engineering problems.

Early exposure to the relevance of physics and mathematics in engineering has been shown to improve student retention and subsequent graduation rates. [7]

A curricular learning community in engineering is created by requiring a cohort of first year students to dual enroll in two or more math, science or engineering courses. Some examples are the following:

- A first semester Intro to Engineering course and Precalculus
- A first semester Intro to Engineering course and Calculus I
- Calculus I, Physics I, and/or Intro to Engineering
- Calculus II, Physics I, and/or Engineering Statics

Each cluster course is taught by a member of the discipline faculty. Although research indicates a simple learning community model with no curricular adaptations will impact first year retention, this model is improved upon when faculty work to integrate the curriculum of the courses. The implementation of problem-based learning is one way to integrate the foundation disciplines of mathematics and physics into significant engineering problems that increase student engagement while improving student problem solving skills.

Key elements of a successful Engineering Learning Community model are:

- Emphasizing to the students the goals of the learning community initially and throughout the semester
- Consistent integration of the clustered course curriculum throughout the semester
- Implementing PBL projects in cluster courses that allow students to apply theoretical engineering, science and mathematics principles in the solution of significant engineering design problems
- Frequent communication between the instructors regarding the status of the clustered courses

It is difficult for students to assess the impact of a learning community experience without knowing what to expect. Emphasizing the goals of the learning community initially at advising and registration and throughout the course will allow students to assess whether or not their expectations have been met. Engineering faculty expect students to work together to solve engineering problems, much as engineers in the field work in teams. This same team structure promoted in the learning community can enable students to successfully complete the first year hurtles of Calculus I, II, Physics, and Engineering Statics, courses where frequently students determine whether or not they will remain in engineering.

It is important for students in a curricular learning community to see the interconnection between the disciplines and courses of the learning community. There are two means in which this can be accomplished. 1) Instructors of the clustered courses work to integrate the curriculum on a consistent basis throughout the semester; and 2) Assigning dual problem based learning projects whose solution requires the integration of content from all clustered courses. Integrating course content on a consistent basis can be challenging depending upon the courses involved. In a learning community linking mathematics and engineering, one method is through the introduction of new course content. Each new topic in mathematics is introduced in the context of an engineering problem or application. Similar applications can then be assigned as additional homework problems. When introducing the concept of the derivative, the following problem integrates the engineering and physics concept of position, velocity and acceleration while helping the student develop a conceptual understanding of a derivative of a function.

The velocity of a vehicle starting from rest at position x=0 is shown in the figure below:

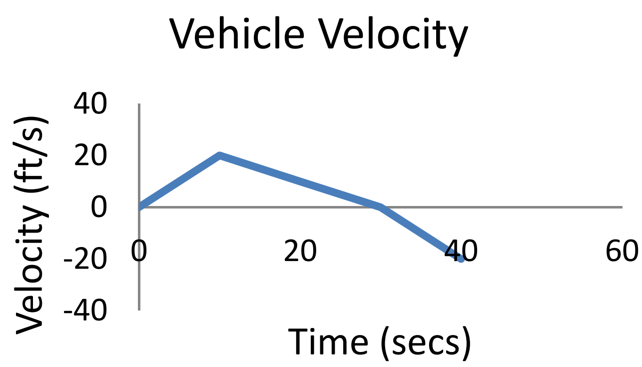

Fig. 4. Example problem for integration of course content.

Knowing that acceleration is the rate of change of velocity, sketch a graph of the acceleration curve. When later introducing integration the same problem can be used with the following question:

"Knowing that velocity is the rate of change of position *x(t)*, if the maximum position is 100 feet and the final position is 20 feet, sketch the graph of the position function *x(t)*." [46]

The introduction of a new topic can also been used as the startup of a PBL project. Introducing the project before covering the content allows students to hypothesize a solution and then build on that hypothesis as student knowledge of the content expands. Function Optimization in Calculus I may be introduced through a PBL project where students optimize the cost of laying an oil pipeline around or through a swamp. A map and scale is given indicating where the pipeline originates and must end. The costs of laying the pipeline through the swamp and on dry land are given per unit foot and student must write the equation for the cost as a function of the path chosen. Engineering faculty appreciate this problem because of its emphasis in modeling and design. No information is given to the students regarding an appropriate shape to model the swamp. Students must determine a shape that will have a mathematical solution and yet accuracy must also be considered. [47]

When linking two or more courses in a learning community model communication between the instructors of the courses is vital. Clustered courses that have common objectives are easier to link that those that do not. For example, Calculus II and Engineering Statics share common topics in applications of integration such as calculating area, volume, surface area, moments, work and pressure against a surface by a fluid. Scheduling and communication are essential when attempting to arrange for both courses to discuss these topics at the same time in the semester. When common objectives are not available it is helpful if flexibility is allowed in the cluster courses for the creation of interdisciplinary learning opportunities. If vector dot products and cross products are not part of the standard Calculus II curriculum, finding a day to discuss these topics in Calculus II will both reinforce the link between mathematics and engineering for the students as well as provide a mathematical framework for the engineering application. The techniques of integration discussed in Calculus II can be motivated by an engineering beam stress problem with a complex distributed load. Allowing for flexibility in the clustered course curriculum creates engaging opportunities for students to approach all problems from an interdisciplinary standpoint and experience where they will utilize the concepts in the future.

The results of a successful curricular learning community can be significant. It is important for institutions to develop a means to assess the impact of the learning community experience through both tracking of student enrollment data as well as student impressions of their first year experience. Focus groups conducted with learning community participants and surveys administered to all first year engineering students can be used to compare student impressions of their learning gains for those in the learning community versus students in the traditional curriculum. Some results that may be seen comparing student impressions of learning gains for learning community students with traditional curriculum students are:

- Greater intent to persist in the engineering field
- Greater student impressions of learning to work as a member of a team
- Larger gains in student ability to identifying and formulating an engineering problem
- Larger gains in student ability to apply engineering principles
- Larger gains in understanding engineering principles
- Larger gains in critical thinking skills
- Significant gains in ability to use mathematics to solve engineering problems
- Significant differences in student ability to find fellow students with whom they could study.

The long term impact of a curricular learning community experience can be assessed by the tracking of an engineering cohort. Data must be collected on retention in engineering, enrollment in subsequent science, math, and engineering courses and grades in these courses. The long term results of a successful learning community are:

- Greater retention in engineering for learning community participants
- Higher grades in key math, science, and engineering courses for learning community participants
- More consistent progression through the engineering curriculum for learning community participants
- Shorter time to degree completion.

Curricular learning communities are not difficult to implement at any size institution and are a perfect match with the engineering curriculum. It is essential for engineering students to learn early in their academic career to work as a part of a team. The learning community experience can create in the first semester, study groups that will assist students through the gateway courses in mathematics, science, and engineering; while providing opportunities to strengthen student problem solving and critical thinking skills, developing interdisciplinary problem solving strategies.

7. Informal public science education and mechanical engineering

With technology moving at such a rapid pace, it has become increasingly important for citizens to be scientifically literate. While children are growing up with these technological advances, there are still several indicators showing that US science literacy is low [48, 49] and experiences with math and science outside of the classroom is crucial to increasing technological literacy not just for children but also the general public. Local science museums and science centers can serve as these pathways to math and science education which forms the background and sparks the interest for engineering. The increased involvement of university-level researchers in science outreach has become part of the national discussion over the last few years with the White House[50, 51]. For some researchers these opportunities are straightforward, since their universities participate in engineering outreach programs to connect to the general public by volunteering at science fairs, offering K-12 teacher professional development opportunities, and by arranging classroom visits [52]. Much more common, however, for many educators such infrastructure just does not exist.

One effective model for informal engineering education and outreach is NanoDays [53] which is a project funded and sustained by the National Science Foundation. NanoDays is a nationwide festival of educational programs about nanoscale science and engineering and its potential impact on the future. Each year, NanoDays events are organized by participants in the Nanoscale Informal Science Education Network (NISE) and take place at over 200 science museums, research centers, and universities across the country from Puerto Rico to Hawaii. NanoDays engages people of all ages in learning about this emerging field of science, which holds the promise of developing revolutionary materials and technologies. The whole idea is to teach the general public about nanotechnology using an informal, hands-on approach in a comfortable, stimulating environment. These activities are scalable and transferable to any age and background. While NanoDays is a national program, it is run locally by science centers and in some cases, university faculty members which creates a successful link between the university and the public. Because the public is generally more comfortable in the science center, NanoDays is conducted in the local science center auditorium. NanoDays programs combine simple hands-on activities for young people with events exploring current research for adults [53]. NanoDays activities demonstrate different, unexpected properties of materials at the nanoscale -- sand that won't get wet even under water, water that won't spill from a teacup, and colors that depend upon particle size [53].

In this model, NanoDays involves faculty who present their research on nanotechnology in a way that is active and engaging and can connect effectively with the public [54]. Undergraduate students are also involved in the hands-on components and demonstrations. Since 2008, interactive presentations have been made by faculty on nanotechnology research such as explosives, new materials for technology, and medicine [54]. It is imperative to choose faculty members that can speak and communicate in a way that reaches the general public. Tips for selecting and training faculty members to be successful in outreach are well-described in [55] and include: use analogies to common day objects when describing scientific phenomena; limit the use of jargon or new words to five (scientific) terms; target talks to 7th graders (12 to 13 year olds); use lots of visuals and demonstrations when possible; and, describe size or scale relative to the human body. The author goes onto say that during training she poses the question to presenters, "How would you explain this to your grandparents?" Lastly and most importantly, she suggests that researchers put their presentation in a narrative or story if possible where the audience can see development from a problem, attempts to solve the problem, a climax and then a conclusion [55] because it has been found that audiences connect with the story of science as well as its facts [56].

Informal science education is an impactful method for relating the general public to current, technology-driven research. NanoDays activities bring university researchers together with science museum educators and the public which creates a unique learning/teaching experience for all and provides real connections for children and adults in engineering.

8. Conclusions

In the highly multi-modal digital age of the youngest generation, science, technology, engineering and math education and learning is confronted with new challenges that require innovative approaches exploiting our understanding of how children and adults learn engineering. Several new structural models for STEM education have been discussed that combine the best features of formal and informal learning. By introducing impactful, engineering education to this generation by integrating literature, technology, and successful teaching and learning methods into their culture, there are no limits to the meaningful contributions that future engineers will make toward improving our way of life.

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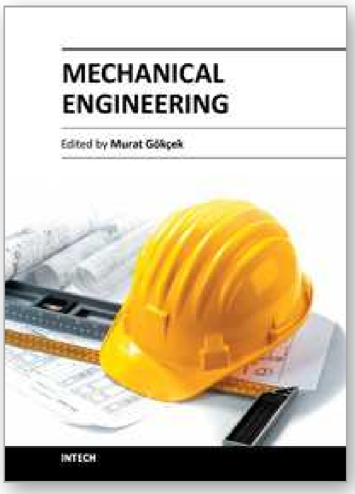

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