AC 2008-2111: IMELT: INTEGRATING MATHEMATICS, ENGINEERING, AND LITERACY IN THE TEACHING OF MATHEMATICS

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Abstract

iMELT is a program developed by mathematics, engineering and education faculty at Louisiana Tech University. The College of Engineering and Science and College of Education have teamed up with area school teachers from under-performing schools to develop engaging projects. These projects utilize techniques that have proven successful in Integrated Engineering and Science Curricula in the college. These techniques include team building, collaborative learning, and hands-on activities.

The purpose of the project was to provide opportunities for the development and active use of math learning activities that integrate best pedagogical practices associated with the use of literacy strategies and connections to real world relevance from the discipline of engineering. Over the course of the project the participants were engaged in activities involving the design and construction of various mechanical and physical devices such as gear assemblies, bridges, levers, vehicles, and catapults. These provide practical activities as a connection to the instruction of science, engineering, and mathematics. Additionally, the positive effect of literacy strategies on student achievement in the math and science disciplines was incorporated into the pedagogical activities.

Teams of participants were charged with the task of identifying the math and science concepts and procedures embedded within the engineering activities and connecting those concepts and procedures to components of their curriculum.

The iMELT project consists of three phases. The first phase is summer professional development camps for the teachers. The second is a series of three weekend workshops, and the third is the implementation of the concepts and projects into the junior high and high school curriculum.

Results of the project are presented which include a sample overview of project and teacher developed activities, as well as feedback from implementation into current curriculum.

iMELT

In his foreword to the national report Before It’s Too Late, John Glenn summarized the state of mathematics and science education across the country when he stated that

“we are failing to capture the interest of our youth for scientific and mathematical ideas. We are not instructing them to the level of competence they will need to live their lives and work at their jobs productively. Perhaps worst of all, we are not challenging their imaginations deeply enough.”

According to the National Science Board’s Science and Engineering Indicators 2004, enrollment in undergraduate engineering and science programs has been in decline since the 1980s. Clearly,
there is a continued need for increased enrollment and retention in science and engineering. Furthermore, NSB urges partnerships between universities and local schools to increase the mathematics and science abilities of high school graduates.

Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) is a major focus of the United States Department of Education. GEAR UP efforts focus on schools where more than 50% of the student population is eligible for free or reduced lunch. In these schools, more than half of the students are failing to achieve basic levels of performance in state criterion-referenced tests in mathematics. Several factors contribute to this lack of success including that, in these schools:

- More than 80% of students live in poverty as evidenced by eligibility for free or reduced-price lunch;
- On average, students attending these schools have a one in three chance of being taught a core subject by a teacher who is not certified or is under qualified for the job;
- Nearly 60% of 8th grade students, and over 60% of 9th grade students achieve below basic levels on state mandated tests in English/Language Arts

In a strand analysis of student performance data conducted in conjunction with GEAR UP partner schools in our region, students consistently demonstrated difficulty in the following areas (listed in priority order): Number and Number Relations, Geometry, Constructed Response, Measurement, and Patterns, Relations, and Functions. For the purposes of project design, it was assumed that student achievement levels and strand analyses are similar across all GEAR UP schools in the state as well as schools with similar characteristics.

The mission of this project, ultimately, is to improve student achievement in mathematics while strengthening literacy skills resulting in improved student achievement in English Language Arts (ELA). iMELT addresses needs of underperforming schools by integrating engineering applications and activities aligned with state curriculum requirements for mathematics. Furthermore iMELT faculty utilize effective, research-based instructional strategies to motivate participants as they engage in practical engineering problems with the aim for K-12 STEM curriculum development. To this end, participants had the opportunity to construct simple machines using K’Nex education kits in order to discover real-world connections with mathematics content of their classroom curriculum. In addition, a variety of problem-solving activities were dedicated to improving ELA performance. These problems lead participants to develop curricula that require students to read, comprehend, and respond; locate, select, and synthesize information; read, analyze, and respond to literature; and apply reasoning and problem-solving skills. All of these ELA strands were deficiencies noted in an analysis of the student data of our regional GEAR UP schools.

“An alternative to simply progressing through a series of exercises that derive from a scope and sequence chart is to expose students to the major features of a subject domain as they arise naturally in problem situations. Activities can be structured so that students are able to explore, explain, extend, and evaluate their progress. Ideas are best introduced when students see a need or a reason for their
The authors utilized the 5 E Learning Cycle Model of Instruction for use as a guide to curriculum development and day-to-day instructional activities. The Learning Cycle, recommends that prior experience and first-hand knowledge gained from new explorations be used when students are learning new concepts, or attempting to connect prior knowledge to higher level understanding. The 5-E model includes five learning experience components: Engage, Explore, Explain, Elaborate, and Evaluate. Each stage builds upon the previous as participants construct new understanding and develop new skills.

Partnerships with schools in our area were developed through a series of Summer Teacher Workshops leading to Professional Development (PD) Weekends during the academic year. The workshops and weekends were designed around a common engineering or science theme. The Summer Teacher Workshops, led by engineering, mathematics, and education faculty at University, provide project-oriented, hands-on engineering and science activities that illustrate practical applications of mathematics and science topics. An overview of the entire project is provided in Figure 1.

![Figure 1: Flow Chart of iMELT](image-url)
Summer Teacher Workshops are held over a two week time period. The goals of the workshops are to demonstrate applications of fundamental mathematics and science topics that can be integrated into math and science classes as well as to develop meaningful and engaging hands-on student projects. Each workshop is conducted by a team of mathematics, education, and engineering faculty. The goal is to develop engineering and science explorations and curriculum for implementation into participant schools. During these preparations, connections between national and state content standards and the mathematics and science showcased in the workshops are identified and discussed. Figure 2 describes both topics presented during the Summer Teacher Workshops and an example of a 5 E model approach to each day.

![Diagram of Summer Workshop Topics and 5 E Approach to Curriculum Development](image)

**Figure 2: Summer Workshop Topics and 5 E Approach to Curriculum Development**
Hands-on experimentation and active learning are used to support the technical topics of iMELT. For example, during the summer camp, the design of a small K’Nex truss (Figure 3) is used to demonstrate basic statics and mechanics of materials concepts, such as: force, compression/tension, and loads. These topics are excellent applications of algebra, geometry, and trigonometry concepts and are fundamental to the design of a bridge. In addition this illustrates more elementary concepts such as number relations, measurement, patterns, and functions, which directly impact the known areas of difficulty found among regional GEAR UP schools.

Professional Development (PD) weekends follow the theme of the Summer Teacher Workshops, but also provide feedback on how the material is being implemented into the school curriculum (Figure 4). The culminating PD weekend includes a Rube-Goldberg competition in which the teachers apply knowledge gained throughout the project. Each teacher is required to develop and incorporate curriculum that is appropriate to their specific grade and subject. Teachers utilize a similarly developed 5 E approach to exposing the students to the material they develop.

A major focus of the PD weekends is to apply the 5 E model to their experience in developing and implementing the curriculum they have created. The outcome of a PD weekend is that the teachers have adjusted and refined their curriculum by a careful evaluation of participants’ experiences. This allows the teachers to engage their students in a revised curriculum. The following PD weekend allows teachers to explore, elaborate, and evaluate this implementation. Figure 5 illustrates one cycle of this model.
The iMELT program included 19 teachers who participated in the Summer Teacher Workshop. There were 18 participants who completed both a pretest and a posttest PLAN mathematics test. Of these, 14 participants increased their posttest score, 1 remained the same, and 3 decreased. The increases ranged from 1 to 15 points with an average increase of 4 points (10%). Decreases ranged from 3 to 5 points with an average decrease of 4 points (10%). Note that 78% (14 of 18) participants increased their score.

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<tr>
<th>Table 1: PLAN Test Results – iMELT Participants</th>
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According to the provisions of the iMELT project, participants were observed implementing concepts learned during the Summer Teacher Workshop. Site coordinators observed the participants teaching on three occasions. The specific duties of the site coordinators were to observe the teachers as they instructed curriculum developed during the summer sessions. These observations as well as the feedback from the participants were re-evaluated during the Professional Development Weekends. In addition, the teachers were required to complete an online component to the iMELT project. Blackboard® was utilized as a collaboration tool, where teachers could share curriculum they developed.

During the Summer Teacher Workshop a total of 14 classroom curriculum projects were developed that spanned across a range of grade levels. Additional curricula were developed by individual teachers as part of the implementation of the project. A sample overview from a curriculum project that was developed during the iMELT project is presented in Figure 6.
Engage:

What is the longest bridge you can make that will support a 100g load with minimal sagging or bending?
- Your team may use materials from a maximum of 1 K’Nex Introduction to Bridge Building set to build the bridge.
- Maximum time allowed: 30 minutes

Once you have completed your bridges, take the required measurements and record your observations.

Explore:

CHALLENGE 3 OBSERVATIONS – 100g load
Rejected Ideas – record the rejected ideas and the reasons for their rejection
Accepted Ideas - record the accepted ideas and the reasons for their acceptance

Draw Your Bridge – Draw a depiction of your final bridge
Maximum span w/o failing __________ cm
Use metric measurements and a drawing to indicate where your bridge failed.

Exploration Question
What changes would you make to strengthen your design so that the beam will remain rigid over a longer distance, even when a load passes over it?

Explain:
List and explain your accepted and rejected ideas based upon mathematic and science principles.

Elaborate:
Engineering Talking Points and Topics for Discussion
How do structural engineers solve the problem of keeping the bridge span structure rigid over long distances?

Evaluate:
Test the bridge to see how it performs

Answer questions related to observations and mathematic content

Figure 6: Sample Overview of Curriculum Developed
iMELT provides opportunities for participants to be engaged in activities involving the design and construction of various mechanical and physical devices such as gear assemblies, bridges, levers, vehicles, and catapults. These provide “real-world” activities as a connection to the instruction of science, engineering, and mathematics. The participants then incorporate these activities into their classrooms.

“The students were more engaged in the lesson than any other lessons I have taught. They liked and enjoyed the hands on activities. I feel that they got more out of this activity because they were more engaged.” – High School Teacher

During the course of the project, teams of participants identified the math and science concepts and procedures that are embedded in hands on engineering activities and connect them to components of their curriculum.

“The kits allowed the students to use a hands-on approach to learning…The students were able to meet the objectives for the lessons. The grade level expectations were also met with the student using the K’NEX kits to solve real life problems.” – Junior High School Teacher

iMELT provided opportunities for the development and active use of math learning activities that integrate best pedagogical practices associated with the use of literacy strategies and connections to real world relevance from the discipline of engineering. Over the course of the project the participants were engaged in activities involving the design and construction of various simple machines. These provide practical activities as a connection to the instruction of STEM subjects.

Bibliography