

# ALERT: An Implementation of Active Learning Techniques in Engineering Technology

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## Abstract

Available data show that many students entering the mechanical engineering technology program at our university, either drop or fail to pass core courses with a C or better. In an effort to prevent this undesirable outcome, we are undertaking the ALERT (Active Learning in Engineering Technology) initiative to address the issue by implementing evidence-based active learning techniques in selected courses to foster students' interest and persistence. Statics, Dynamics and Thermodynamics are the target courses. Statics is a gateway course foundational to the rest of the program, Dynamics is taken right after Statics, and Thermodynamics is one of the most challenging senior level courses. These courses are serving as the avenues for measuring the effectiveness of using active learning techniques. The specific techniques we are implementing are: *in-class experiments, just-in-time teaching, team quizzes, and students as teachers*. On a broader impact, the ALERT initiative will be the launch pad for implementing active learning techniques in other courses throughout the program.

## 1. Introduction

Active learning is a teaching method to involve students more directly in the learning process by engaging them in two aspects: a) doing things and b) thinking about the things they are doing [1]. The central element of active learning is the incorporation of specific activities during class time that engage students with the course material. This transforms the student from being a passive recipient of knowledge, with the instructor as the expert, to an active learner who discovers and engages with new knowledge as a result of classroom activities. Research has found that students will remember more content if brief activities are introduced to the lecture rather than trying to push through as much material as possible in a given session. In cooperative learning specifically, structured group activities where students pursue a common goal and require collaboration to reach the goal are used. In particular, there is a focus on cooperative incentives instead of competition so as to promote learning. Available evidence suggests that faculty should structure their courses to promote collaborative and cooperative environments. The entire course

need not be team-based, nor must individual responsibility be absent, as seen by the emphasis on individual accountability in cooperative learning [2].

Based on research on college teaching and learning, Chickering et al. suggested that good practice in undergraduate education: (1) encourages contacts between students and faculty; (2) develops reciprocity and cooperation among students; (3) uses active learning techniques; (4) gives prompt feedback; (5) emphasizes time on task; (6) communicates high expectations; and (7) respects diverse talents and ways of learning [3]. Evidence-based research on learning also indicates that when students are actively involved in their education, they are more successful and less likely to fail. Freeman et al. tested this hypothesis by reviewing and analyzing 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning [4]. Comparing the results, they indicated that average examination scores were improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning.

In a survey of pre/post-data that was performed by Hake for 6542 students in 62 introductory physics courses, it was quantitatively shown that the use of interactive-engagement (IE) methods can improve students' problem-solving skills beyond that obtained in traditional teaching techniques [5]. To date, several evidence-based active-learning techniques have been developed and introduced in the literature in order to enhance interactive engagement during classroom time. Among these methods are: group quizzes/assignments, just-in-time teaching (aka. JiTT), peer-instruction, as well as in-class experiments for more applied engineering courses, etc. In the following, some studies that examine these specific techniques will be described in more detail.

While active learning techniques have been acknowledged as effective means of improving student engagement in their learning, pressures of time and cost have led to many hands-on activities being reduced within engineering programs, or to their being replaced with on-line alternatives [6]. As a way to counterbalance this adverse tendency, a variety of low-cost hands-on activities have been developed to promote student engagement and improve learning outcomes in mechanics courses. Examples in the literature include:

- 1) Using Hands-On Activities to Engage Students in Engineering Mechanics [7]: In this work, a set of low cost, hands-on, interactive experiments that demonstrated the underlying theory and helped students understand the basic engineering mechanics principles were developed for students to use in small groups. A comparison of student pass rates for the selected courses demonstrated that the pass rates were higher than those achieved in similar international foundation engineering courses. A high degree of student engagement and involvement while doing the experiments was also observed.
- 2) Improving Retention of Student Understanding by Use of Hands-on Experiments in Statics [8]: In this work, a large theory class in statics was divided into smaller discussion

sections with hands-on experiments being implemented in the discussion sections. Students overwhelmingly approved of the lab exercises, which provided a better understanding of the theory on which the lab exercises were based. Being actively involved in the course gave students ownership. In the first two semesters of implementation, the use of lab exercises resulted in slight increases in averages on homework and exam grades.

- 3) Experiments for Statics [9]: In this work, a set of experiments were developed to give students a connection between the material presented in the text and observations of the behavior of the systems in the classroom. In addition to sparking student attention and interest, the experiments also offered a vehicle to other concepts like analysis and presentation of data. The students responded positively to the introduction of the experiments.
- 4) Hands-On Learning for Statics in the Smaller Classroom and Potential Scale-Up to the Larger Lecture [10]: In this work, a series of cheap, quick experiments were designed to introduce statics concepts and help students discover knowledge and see the engineering principles in action. In addition, a design competition was assigned at the mid-point of the semester. The students were shown a series of sculptures designed using static equilibrium. The competition goal was to create a sculpture/mobile/device/assembly that was statically determinate and in static equilibrium, but yet looked like it should fall over. An external evaluation plan was prepared and implemented. The evaluators readily identified the students as “engaged in creative problem solving”.

Group assignments and tests can also be used to promote cooperative activities in the classroom. For example, inquiry-based learning activities (IBLA) consist of presenting teams of students with a physical situation and asking them to predict what will happen. Self et al. developed one of the first Inquiry-based learning activities (IBLA) for a Dynamics course, which involves the direction of friction and motion for a rolling object and assigning quizzes the day before the activity/experiment [11]. They encouraged students to think about the situation before coming to class, and to make predictions about the behavior of the system. During class, students are given time to perform the “experiments” based on the quiz from the day before. After roughly 20 minutes, the class discussed the results and then took a “team quiz”. This quiz involved a slightly different outline to see how well the teams could transfer the information learned during the activity. Students’ predictions and worksheet are reviewed by the research team to evaluate their understanding through the course of the activity. As students run the experiment themselves and observe the results, the physical world, rather than the professor, acts as the “authority”.

Just-in-Time-Teaching (JiTT) is another approach to active-learning, which helps faculty promote students’ engagement and learning in the classroom by utilizing advanced communication technologies. This pedagogy is aimed to ensure that the instructor can adjust the teaching content based on the students’ feedback in the classroom [12]. Ieta et al. evaluated the effectiveness and appropriateness of JiTT across different disciplines as well as different class levels. Students’ surveys in this work indicated that the majority of students regardless of their discipline and class level felt that this pedagogy helped them learn more effectively and actively

[12]. In another study, Kitch investigated the effectiveness of JiTT and peer instruction in his specific discipline (civil engineering) [13]. He collected and analyzed data from 296 students over 4 years (8 different course offerings by 3 different instructors). He concluded that students found computational problem sets as the most effective learning tool in these classes, which is expected due to the problem-solving nature of most of the engineering courses. Interestingly, students found just-in-time teaching and peer instruction the next most effective tools. The majority of students reported that JiTT helped them be on-schedule and more mindful in the classroom [13].

In another study that was supported by NSF (Division of Undergraduate Education: Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (DUE: TUES)), Krause et al. investigated an interactive cyber-enabled web learning environment by utilizing *Blackboard*, *Concept Warehouse* ([cw.edudiv.org](http://cw.edudiv.org)), *Concept Inventory Hub* (ciHub) ([dev.cihub.org](http://dev.cihub.org)), *YouTube Video Tutorials*, etc. [14]. With this project, four different institutions implement Just-in-Time Teaching (JiTT) with Interactive Frequent Formative Feedback (JiTTIFFF). Using cyber-enabled web tools, students were provided with repeated formative feedback during the semester. Results of this project indicated very positive reactions from students as well as improved learning and retention.

In a more specific application of the JiTT pedagogy, Liberatore et al. investigated its effectiveness in an introductory thermodynamics course [15]. They evaluated the effectiveness of JiTT by comparing the students' performance between a group with JiTT enforcement in the classroom and a control group who were taught traditionally. The overall scores among those students who were taught with JiTT exercises were improved. It is noteworthy that they found JiTT more beneficial and impactful to average students as compared to its impacts on high- and low- performing students.

In the work that is the subject of this paper, the authors designed a 2-year project to examine the implementation of different active learning approaches and their impacts in the mechanical engineering technology program at Wayne State University. Among the evidence-based active learning pedagogies, authors have decided to implement in-class experiments, group quizzes, just-in-time teaching, and students as the teachers; in their courses Statics, Dynamics and Applied Thermodynamics. In the following, the project description including the rationale for the selected courses and corresponding pedagogies as well as the implementation plan will be explained in detail.

## 2. Project Motivation

The ALERT initiative described in this paper is an ongoing implementation of evidence-based active learning techniques within our Mechanical Engineering Technology (MCT) program. This is an upper division-only program. Incoming students typically transfer from area Community Colleges and usually hold Associates degrees. Of the total 128 credits required for the degree, students can normally transfer up to 64 credits from a Community College. There are articulation

agreements in place allowing for the transfer of more than the standard 64 credits from select institutions. The MCT program structure is outlined in Table 1. It consists of a common upper division technical core (25 credits), three parallel tracks allowing students to choose an area of specialization (8 – 9 credits), and three electives (8 – 9 credits). The table also shows the student learning outcomes (see Appendix A for detailed definitions) created to fulfill the program’s educational objectives, and satisfy ABET accreditation requirements. The numbers in the table represent the level of a course’s contribution to a given outcome (3 being the highest).

Table 1: MCT Program Structure

Credit	MCT Curriculum (Total Credit Hours: 128)	Contribution to Student Learning Outcomes														
		a	b	c	d	e	f	g	h	i	j	k	M1	M2	M3	
60	<i>Lower Division Science/Technical Courses</i>															
27	<i>General Education</i>															
<b>25</b>	<b><i>Upper Division Technical Core</i></b>															
3	<b>ET3030 - Statics</b>	2	3				2						2			
3	<b>ET3050 - Dynamics</b>	2	3										3			
3	ET3850 - Reliability & Engg. Statistics	2	3	3	1		2		1		1					
3	ET3870 - Engineering Economic Analysis	3	2			3	1	2			1					
3	ET5870 - Engineering Project Management	2				2	2		1	1		3				
3	MCT3010 - Instrumentation	2		3	2	3		3		2						
1	MIT 3500 - Manufacturing Processes Lab	3				3		2		1		2				2
3	<b>MCT 4150 - Applied Thermodynamics</b>	2	2	2	2	1	3	2			1				3	
3	ET4999 - Senior Project	2			3			3	2	2	3	2		3		
8 - 9	<i>Track-Specific Technical Courses</i>															
8 - 9	<i>Upper Division Technical Electives</i>															

The courses highlighted in Table 1 are the ones targeted in the ALERT initiative. Historically, they have shown high drop rates with negative impact on the overall success of the program. The drop and success rates in these courses over the last five years are given in Table 2.

Table 2: Student Drop/Success Rates in Target Courses

Course	Enrolled	Dropped	Grade C or better	Drop rate	Success rate (w/o drop)
ET 3030 - Statics	85	26	35	30.6%	59.3%
ET 3050 - Dynamics	72	17	46	23.6%	83.6%
MCT 4150 - Thermodynamics	76	19	50	25.0%	87.7%

Statics is the first technical course for incoming students. It is a prerequisite for many other courses and thus it is foundational to the rest of the program. Dynamics is a course that students are required to take right after Statics, while Thermodynamics is a senior level course which students tend to find very challenging. These three courses were selected to serve as good avenues to measure the effectiveness of implementing the evidence-based instructional methods

entailed in the ALERT initiative. As Table 2 shows, there are high drop rates for all three courses. And even for persisting students, the success rates are not satisfactory. The Statics course has both the highest drop rate and the lowest success rate. As the first technical course in the program, it serves as a gateway to the rest of the program. A drop rate of 30% combined with a 59% success rate means that less than 42% of students attempting the Statics course complete it successfully. Similarly, less than 64% and 66% of students attempting the Dynamics and Thermodynamics courses complete these courses successfully. While this implies that students who are successful in Statics are more likely to achieve higher success levels in the subsequent courses such Dynamics and Thermodynamics, the successful completion rate is still less than desired. Because the target courses are all required, success or failure in these courses has a significant impact on the overall MCT program.

The techniques being implemented as part of the ALERT initiative are intended to improve overall student success rates in the MCT program. Specifically, we are engaging students in active learning strategies right from the start of the semester to capture students' interest, and promote persistence. The specific evidence-based activities that are being adopted in the target courses are described in the implementation plan immediately following.

### 3. Implementation Plan

As mentioned in Section 1 of this paper, the literature provides a wide variety of evidence-based teaching and learning strategies that can be used to improve student attainment of learning outcomes. The ALERT initiative is focusing on implementing aspects of different strategies through the following specific activities:

Table 3: The Felder-Silverman Learning Style Model [16, 17].

<i>Sensing learners</i> (concrete, practical, oriented toward facts and procedures)	vs.	<i>Intuitive learners</i> (conceptual, innovative, oriented toward theories and meanings);
<i>Visual learners</i> (prefer visual representations of presented material)	vs.	<i>Verbal learners</i> (prefer written and spoken explanations);
<i>Inductive learners</i> (prefer presentations that proceed from the specific to the general)	vs.	<i>Deductive learners</i> (prefer presentations that go from the general to the specific);
<i>Active learners</i> (learn by trying things out, working with others)	vs.	<i>Reflective learners</i> (learn by thinking things through, working alone);
<i>Global learners</i> (holistic, systems thinkers, learn in large leaps)	vs.	<i>Sequential learners</i> (linear, orderly, learn in small incremental steps).

#### 3.1 In-class Experiments

An important way to attract students and promote their understanding is to assist them conceptualize the theories through hands-on experiments. This is especially so for engineering technology students whose learning styles tend towards the active rather than conceptual. In the Felder-Silverman learning style model shown in Table 3, engineering and engineering technology students generally tend to be on the left side of the model and consequently benefit

greatly from hands-on experiments. We have designed small interactive experiments for students to perform during class and ‘discover’ new concepts before the theoretical material is taught.

Because of the hands-on orientation of Engineering Technology programs, and their emphasis on providing application-oriented instruction, this is a high priority technique which is being implemented in all three target courses. In addition to in-class experiments, each target course also explores the application of at least one additional technique as detailed in Section 4.

### ***3.2 Just-in-Time Teaching (JiTT)***

Just-in-Time-Teaching (JiTT) is a form of active learning strategy that is designed to collect feedback from students based on both in-class and out-of-the-class activities to better guide the teaching preparations and instructional activities. Consequently, the instructor adapts the class activities based on students' common misunderstandings and/or difficulties. For this implementation of the ALERT initiative, lecture notes/presentations as well as other instructional materials such as videos, examples, etc. will be posted on Blackboard. During the lectures, students will be given multiple-choice questions to answer, which will have the following benefits:

- a) Improved student engagement: The lectures will be interrupted several times by giving students a short-answer problem to work on in groups. This will help students learn the materials step by step instead of having to continuously listen to a 1-hour lecture.
- b) Instructor awareness: The feedback from the short-answer problems gives the instructor the opportunity to more mindfully lead the rest of the lecture.

### ***3.3 Team Quizzes***

A common concern is that there are always students who hesitate to ask questions. One way to address this concern is to increase cooperative activities in the class so that students have the opportunity to interact with each other and with the instructor. Team quizzes can promote such interaction. However, careful consideration must be given to the design of these quizzes, i.e. fair assessment and guaranteed participation of all group members should be taken into account. For this implementation of the ALERT initiative, we are designing two-stage quizzes based on the students' homework assignments. In the first stage, students will work on the quizzes individually and their answers will be collected. Students will then be assigned to groups of 2 - 3 members and the same quiz will be assigned to the groups. This will ensure that each student has thought individually about the problems, and will promote student collaboration in a group to share their understanding of the problems and correct each other as they strive to improve their overall score. The quiz problems are being designed to be challenging enough that student discussions and team work are promoted.

### ***3.4 Students as the Teachers***

The Students as the Teachers strategy entails a student or group of students taking on the role of instructor. This promotes deep learning on the part of the student(s) involved. For the ALERT initiative, this is being implemented by providing an extra homework problem to solve outside of

class. The designated student(s) then show the rest of the class how to tackle the problem in a subsequent class session. The instructors are available to the students to make sure they understand that particular problem and can teach it to their peers.

The implementation of the various techniques discussed across the three target courses is summarized in Table 4. Because the Mechanical Engineering Technology program is designed to be hands-on oriented, all instruction would benefit from application-orientated teaching techniques. Therefore, in-class experiments are being implemented in all three courses.

Table 4: Implementation of Active Learning Techniques in Target Courses.

Target Course	Techniques Implemented			
	In-Class Experiments	Just-in-Time Teaching	Team Quizzes	Students as the Teachers
Statics	X			X
Dynamics	X		X	
Thermodynamics	X	X		

#### 4. Discussion

In this section, the implementation process for the selected pedagogies is described and some preliminary results are presented. Table 4 above maps the target courses to their corresponding active-learning pedagogies.

##### *4.1 In-Class Experiments – Design and Implementation Process*

The authors have designed in-class hands-on experiments for all three courses to help students conceptualize the new knowledge being acquired. For example, the redesigned Statics course is currently being offered as of this writing. The other two courses will be offered next semester. The hands-on experiments listed in Table 5 have been developed for the Statics course.

Detailed instruction for carrying out each experiment are provided. The students are organized in small groups of 2-3 students to work on each experiment. Of the experiments that have been done so far, it has been observed that students are much more engaged with one another and with the material. For example, students were observed asking each other questions about the steps required to carry out the experiment, questioning the experimental results, and taking turns to carry out different steps of the experiment. Students were also observed as being more attentive to the lecture delivery immediately following the experiment. While the work is still ongoing and final testing has not yet been done, we fully expect the in-class experiments to result in deeper understanding of the course material for the students. It is further anticipated that through these hands-on experiences, students' attention and interest will be captured from the very beginning of the course resulting in decreased course the drop rates.



Table 5: In-Class Experiments for Statics

Experiment Topic	Learning Objectives
Force Measurement	Determine the extensions that result in a spring from which various masses are hang. Apply Hooke's law to determine the corresponding force values.
2-Dimensional Force Components and Resultants	Observe the effects of three concurrent 2-d forces of varying magnitudes and directions acting simultaneously on a body. Using trial and error, find a single force that fully negates the effects of the other two forces.
Moment of a Force in a Plane	Observe two non-concurrent 2-d forces acting simultaneously on a body. Investigate the relationship between the magnitude and position of the forces and the resulting rotational effects.
Equilibrium of 2-Dimensional Rigid Bodies	Observe the effects of three non-concurrent 2-d forces of varying magnitudes and directions acting simultaneously on a torque wheel. Using trial and error, find a single force that fully negates the effects of the other two forces.
Center of Mass	Locate the center of gravity of an asymmetrical body. What happens when the body is balanced at the center of gravity?

Among the in-class experiments designed to be used in the Dynamics course is a rotating beam designed and made by our senior project students. With this experiment, two students can sit on the beam (one student at each end), which is then set in rotary motion. One student then tries to throw a ball to the second student to catch. This is a very difficult feat to accomplish while the beam is rotating. The failure to throw directly to the selected target gives the students a better understanding of the tangible meaning of the concept of the "Coriolis Effect". Other examples of in-class experiments for Dynamics include a projectile launcher system for students to study projectile motion and measure the initial speed using two photogate beams built in a system; and demonstrating the conservation of angular momentum by a person holding a spinning a bicycle wheel with two handles while standing on a low friction stool or platform that is free to rotate.

Examples of the in-class experiments for the Thermodynamics course include: ideal gas relations, phase change in a refrigeration cycle, sterling engine, etc. With these experiments, the instructor has the opportunity to walk students through discovering the thermodynamics concepts instead of lecturing them traditionally.

#### **4.2 Other Active Learning Pedagogies – Implementation Process**

In addition to the in-class experiments, each course will also benefit from at least one other teaching pedagogy, as detailed in Table 4. The implementation of some of these strategies is discussed in more detail below. The team will take time to debrief each other on the impact of these additional techniques that will not necessarily have been implemented by each team

member. This strategy allows each team member to learn about the effectiveness of other pedagogies implemented by the rest of the team.

### **Team Quizzes**

The Team Quiz technique is being implemented in the Dynamics course. Excluding classroom sessions that will be dedicated to mid-term and final exams and review sessions, there are fourteen weeks of classroom sessions. In this period of time, students have six assignments to submit. To implement the this pedagogy without interrupting the existing schedule, six team quizzes will be assigned to students, where each quiz will be based on an assignment that has been turned in by students in that session. Quizzes are designed to take 15-20 minutes. In these quizzes, students have around 5-10 minutes to work on the quiz individually and submit their individual answers. They are then assigned to perform the same quiz in their groups and turn a single solution per group. For grading such quizzes, each student' grade will be based on his/her individual solution (40%) and his/her group solution (60%).

### **Just-in-Time Teaching (JiTT)**

The JiTT technique is being implemented in the Thermodynamics course. The instructor is developing weekly materials for students to study before the class time so that they can prepare for the upcoming lecture. In addition to the provided materials, students will be given a short quiz on those materials and the ones previously taught. The quizzes are due an hour before meeting in the classroom. This gives the instructor a chance to look at the quizzes before the class time and adjust the lecture according to students' feedback, i.e. their weaknesses and strengths.

## **5. Conclusions**

The authors are undertaking a 2-year project to implement evidence-based active learning pedagogies in the Mechanical Engineering Technology (MCT) program at Wayne State University. The target courses are selected from the core courses of the program: Statics, Dynamics and Thermodynamics. The project duration will ensure that each course is taught at least twice during the course of the project. Authors have designed and are implementing in-class experiments for all three courses to help students conceptualize theories that they are taught. Preliminary observations indicate that students are more engaged with the course material and are more involved in meaningful discussions with each other after experiencing these new teaching techniques. Capturing students' attention at the very beginning of the course is a promising leading indicator that drop rates will decline while student's understanding of the course materials will increase. The authors plan to gather additional information from students' feedback in the classroom as well as end-of-semester performance to share with the broader engineering education community.

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## Appendix A

### General Criteria for Student Outcomes required by ABET [18]:

- a. an ability to select and apply the knowledge, techniques, skills, and modern tools of their disciplines to broadly-defined engineering technology activities,
- b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies,
- c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes,
- d. an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives,
- e. an ability to function effectively as a member or leader on a technical team,
- f. an ability to identify, analyze, and solve broadly-defined engineering technology problems,
- g. an ability to communicate effectively regarding broadly-defined engineering technology activities,
- h. an understanding of the need for and an ability to engage in self-directed continuing professional development,
- i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity,
- j. a knowledge of the impact of engineering technology solutions in a societal and global context, and
- k. a commitment to quality, timeliness, and continuous improvement.

### MCT Program Specific Student Outcomes Developed in Engineering Technology Division at Wayne State University:

**M1** – MCT Design Track: Students in this track will demonstrate the ability to apply principles of materials and mechanics to the design and analysis of mechanical components and mechanisms; consistent with industry codes, specifications, and standards.

**M2** – MCT Energy Track: Students in this track will demonstrate the ability to apply principles of thermo-fluid sciences to the design and analysis of energy systems; consistent with industry codes, specifications, and standards.

**M3** – MCT Manufacturing Track: Students in this track will demonstrate the ability to apply principles of materials and production techniques to the planning, implementation, and control of manufacturing processes; consistent with industry codes, specifications, and standards.