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# Flipped Classroom or Active Learning: Integrating Alternative Teaching Methods into Engineering Technology Curriculum

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## Abstract

This paper looks at the characteristics of the flipped classroom and the significance of how this may or may not change the traditional engineering technology approach to teaching. The lessons learned from flipping an engineering technology class in operations management will be presented along with assessment of student learning in the class. Examples of traditional engineering technology courses utilizing active learning techniques that are not supportive of the flipped methodology are also presented. Finally, points for discussion will be explored regarding how to determine when the flipped classroom should be used and when it may not be the best approach in an already established active learning environment.


## Introduction

In recent decades there has been a growing integration of technology-based instruction in higher education [1]. The traditional classroom based instruction is being re-worked to move "instruction" to the individual learner level in order to free up time so that students can spend more time with instructors and classmates. Hence, students participate and interact when in the classroom rather than just listening to lectures. Many instructors are using this new found time to have students participate in active learning techniques and provide time to freely exchange ideas that enhance learning material.

Whereas it is true that "flipping the classroom" is one way to allow for a more interactive learning process, many engineering technology educators have been integrating methods of interactive learning long before technology provided an easy means to flip classes. One of the main reasons that engineering technology curricula was introduced was to allow for more hands-on application of engineering principles. This spectrum of the engineering curricula has always required active learning techniques and problem based learning activities to help students understand the material.

In recent past, there have been several alternative classroom designs that support active learning whether or not the flipped classroom pedagogy is used. These arrangements typically feature tables with moveable seating that support small group work. The tables are often paired with additional learning technologies such as whiteboards and student computer–projection capabilities for sharing work and wireless internet access to retrieve resources [2]. At Purdue University Northwest, this classroom design was recently implemented for use in some of the engineering technology courses. Since the new classroom design incorporated up-to-date learning technologies that have been used to support flipped classroom implementations, it was assumed that the faculty utilizing the new workspace would also integrate new teaching initiatives, mainly the "flipped classroom" technique.

## Flipping an Engineering Technology Course

Research conducted by DeLozier and Rhodes highlighted that there is no single model for a flipped classroom. However, they did note that the flipped classroom is typically characterized by a course structure with instructional content being assigned as homework before coming to class and in-class time being spent by students to work problems and engage in collaborative learning. Furthermore, they found little direct evidence exists regarding student learning outcomes or academic performance in a flipped versus traditional lecture-based classroom [3]. Therefore, instructors need to carefully consider why they would want to implement a flipped classroom before just jumping in because it is the new pedagogical approach.

The engineering technology faculty at Purdue University Northwest found the six step method used by Albert and Beatty [4] to apply a flipped classroom pedagogical approach very useful. Their steps included:

1. Convert each chapter to video capture, broken into several learning segments.
2. Redesign the curriculum: develop/select content for in-class discussion that promotes active learning focused on key course concepts.
3. Create incentives for student participation.
4. Provide students with an understanding of the flipped classroom model.
5. Create a sense of ownership and commitment.
6. Make other key changes to syllabus and supporting material.

When attempting to convert an existing engineering technology course to a flipped pedagogy, these steps appeared logical and easy to follow. However, several questions were asked by the authors of this paper when attempting to implement these changes, such as, how can results from flipping be measured and is it measured quantitatively or qualitatively? Albert and Beatty also found, similar to DeLozier and Rhodes, that there are limited studies on the impact of flipped classrooms in higher education on grades and of these, a few studies have actually shown there is no impact on grades [4]. So why change to a flipped classroom approach if active learning is already working for engineering technology educators?

<u>Implementing a flipped engineering technology course</u>

In Spring 2017, a junior level engineering technology course, IET 22400, Production Planning and Control, was slated as one of the courses to be taught in the new alternative classroom design in the engineering technology department at Purdue University Northwest. Since this classroom design had been associated with the flipped classroom pedagogy, the course was assumed to be a candidate for change to the new flipped format. The instructor followed the previously noted six-step approach to redesigning a course for the flipped approach. Pre-recorded lectures were available via the text book publisher along with various other learning tools that supported students learning at their own pace outside of the classroom.

Studies have shown that students prefer learning content in this manner prior to class and using class time for applied learning. Similar studies showing that students who learned through a flipped classroom approach considered themselves more engaged than students attending traditional courses and were more satisfied with the learning environment compared to other treatment groups [5]. Unfortunately, this was not this instructor’s experience. End of course surveys resulted in a mixed array of student results with comments that indicated diametrically opposing experiences. For example, in response to the open ended question asking for feedback on improvements to the course one student indicated “It’s perfect!” while the comment directly after this one indicated “Don’t do the flipping, it is too confusing.” These type of comments most notably would be influenced by the student learning styles, indicating some students like it (possibly the self-starters) while other do not (possibly those needing more direction).

Furthermore, when determining how to assess if the flipped classroom format is actually having an impact on learning, the instructor and other engineering technology colleagues struggled with appropriate assessment methods. In order to determine if learning is taking place, a base line learning knowledge level is required. This can only be done with the luxury of multiple course offerings to establish a control. Without the luxury of a control group, the instructor and other colleagues approached assessment in the flipped classroom based on a pre and post-assessment method. However, this information is not adequate as all post-assessment results must be compared relative to a non-flipped method. It has been determined that the next course offering for this course will utilize active learning but the flipped classroom technique will not be used. The instructor hopes to gather the missing data at that time for comparison.

In addition to baseline knowledge comparison, a simple review of daily assignments and exams seems to indicate lower student grades than typically seen by the instructor (averages in the 70’s%). This could have been attributed to other changes such as the introduction of an e-book, whereas a traditional text version was used prior to the semester when the flipped approach was used. General confusion appeared to result for many students as implementing a flipped format also includes changing the tried and true methods of learning that many students are comfortable with. At times, it became unclear what topic students should be working on. Solving problems in-class often resulted in too short of a timeframe. This required several class periods of bouncing from one topic to another that did not coincide with external lecture reviews in order to answer questions and make sure all students had the answers they needed.

On a larger assessment scale, annual changes made to courses in the engineering technology department at Purdue University Northwest are tracked via a curriculum update form that summarizes data that is used to assess student achievement of course learning objectives both qualitatively and qualitatively. The data collected correlates grades to objectives as well as results from surveys taken by students at the end of the course (see Fig. 1). On review of the correlation between course learning outcomes, course assessment grades and student subjective survey results (see Fig. 1), it appears that although the students averaged grades in the 70’s% (indicating average results with students missing much expected knowledge), the student’s corresponding subjective responses (4.3 to 4.6 on a 5.0 scale) indicated that they felt they had a good grasp of the material. Based on these results (see Fig. 2), along with the pre and post-assessment results discussed earlier, it has been determined that this course when taught next, will be redesigned to include active learning techniques but will not utilize the flipped methodology in order to establish a proper baseline of student knowledge.

| IET 22400 - Produciton Planning and Control Course Assessment Tool – Instructor and Student Course Objective Assessment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Semester:** | **Spring 17** | | | **Instructor:** | | | | | | | | | | |
| | | Course Embedded Assessment of Student Performance | | | | | | Student Evaluation (%) | | | | | | |
| Course Objective | Supported Program Educational Outcome | Assessment Tool 1 | Score (%) | Assessment Tool 2 | Score (%) | Assessment Tool 3 | Score (%) | E | G | A | P | NA | Composite |
| 1. 1. Define productivity and explain its importance to organizations and countries | a | Assignment 1 | 86 | Exam 1 | 78 | | | 56.25 | 31.25 | 12.5 | 0 | 0 | **4.4** |
| 2. Solve forecasting problems, perform reliability calculations, and explain redundancy in systems. | b, f | Assignment 2 | 73 | Exam 1 | 78 | | | 56.25 | 37.5 | 6.25 | 0 | 0 | **4.5** |
| 3. Formulate and solve linear programming models using graphical methods and interpret computer solutions of linear programming problems. | b, f | Assignment 4 | 91 | Exam 2 | 77 | | | 37.5 | 50 | 12.5 | 0 | 0 | **4.3** |
| 4. Describe the basic types of facility layouts and solve simple line balancing problems. | g | Assignment 5 | 82 | Exam 2 | 77 | | | 50 | 37.5 | 12.5 | 0 | 0 | **4.4** |
| 5. Define quality, why it's important and the consequences of poor quality. | k | Exam 2 | 77 | | | | | 50 | 43.75 | 6.25 | 0 | 0 | **4.4** |
| 6. Utilize various methods of work measurement and describe how work measurement supports improved productivity. | b | Assignment 6 | 79 | Exam 2 | 77 | | | 62.5 | 31.25 | 6.25 | 0 | 0 | **4.6** |
| 7. Explain supplier management techniques and understand evaluation tools. | g | Exam 3 | 72 | | | | | 50 | 31.25 | 18.75 | 0 | 0 | **4.3** |
| 8. Understand tools of inventory management from economic order quantities, quantity discount models, economic run size to the ins and outs of material resource planning. | b | Assignment 8 | 83 | Exam 3 | 72 | | | 50 | 37.5 | 12.5 | 0 | 0 | **4.4** |
| 9. Explain lean manufacturing principles and cellular layout. | a | Assignment 9 | 89 | Exam 3 | 72 | | | 50 | 43.75 | 6.25 | 0 | 0 | **4.4** |
| Comments: Averages of exams were generally over 70% but this does indicate many students did not understand the material as many were below 70%. Student responses indicated they thought they understood the material. Some of the lower grades could be attributed to using e-book with alternate teaching methods. Course objectives 5 and 7 are not really a focus of this course, both topics are courses in themselves and not required in this course. They are generally incorporated and assessed via exam questions but no specific focus is placed on these topics during the semester. These two objecitves should be removed from this course bringing the number of objectives down to a more resonable 7 objectives being assessed in this course. | | | | | | | | Number of responses: | | | | 16 | |

Fig. 1
Course learning outcomes with correlated course assessment grades
and student subjective survey results
Spring 2017, IET 22400

| IET 22400 Instructor Update Information | | | |
|---|---|---|---|
| **Date Submitted: Spring 2017** | | **Date to be Reviewed: May 2018** | |
| **Responsible faculty for the review: xxx** | | | |
| **Type of Update** | | | |
| ☐ New Edition of the Text | ☐ New Text Adopted | ☐ New Software | ☑ Teaching Method |
| ☐ New Laboratory Equipment | ☐ Lab Material Update | ☑ Teaching Initiative | ☐ Other |
| Description of Condition Prior to / After Update: | | | |
| This course has been taught by LTL faculty since at least 2011 with no major course changes. This semester several changes in teaching method were implemented: A flipped classroom pedegogy was piloted this semester. The e-book review material added; pre-recorded lectures available via book publisher; software that was supposed to be available through publisher for active learning components in classroom was not available. Active portion of course focused on homework problems and then reverted to lecture reviews mid semester based on student feedback. | | | |
| Assessment Method Used to Evaluate Short or Long Term Results: | | | |
| Student feedback and grades | | | |

Fig. 2
Instructor Summary of course
Spring 2017, IET 22400

<u>Traditional Engineering Technology Courses Implementing Active Learning Exercises</u>

After teaching the IET 22400 course with a flipped classroom approach in the newly renovated alternative classroom design, the instructor questioned the impact of the flipped approach on students. Discussion regarding the outcome and the assessment results with other faculty in the engineering technology program revealed that other faculty were having similar challenges figuring out how to properly assess the changes from lecture-based methods to the flipped classroom method. The question also arose that if a course is currently designed with active learning components, as so many engineering technology courses already are, then what is the advantage of changing to the flipped classroom approach?

For the flipped classroom to work effectively, students must be sufficiently motivated and engaged cognitively with the pre-class material to enter the discussion or group work with adequate knowledge. This means the flipped classroom requires a process of social negotiation during collaborative group learning to reach a consensus understanding based on the students' existing knowledge base [6]. With the traditional active learning approach, this requirement of pre-class knowledge is not required, only the social negotiation during collaborative group learning remains.

Purdue University Northwest's engineering technology department has many examples of courses that have been adapted over the past decades to include active learning components as a fundamental foundation for how the course is taught. The success of these efforts has been captured through assessment measures documented on the engineering technology department's curriculum update forms (see Fig. 1 and 2 discussed previously for examples). Two fundamental examples of traditional active learning courses included in the engineering technology department are an introductory ergonomics course for freshman, IET10600, Principles of Ergonomics, and a senior level course, Computer Integrated Design and Manufacturing, MET46100.

Active Learning Exercises Implementation: Example 1

The introductory ergonomics course was taught six times from 1998 to 2003 utilizing a standard lecture-based format after which active learning exercises were introduced over a period of several years. These exercises were focused on the more difficult to grasp ergonomics concepts that students appeared to be struggling with. Following are an explanation of the active learning exercises that were added and how they improved upon the traditional lecture-based method of instruction.

Active Learning Exercise #1: Developing Anthropometric Data

> Objective: Develop a table of anthropometric stature data in order to fully understand the statistics behind currently published data tables.
>
> Lecture vs. Active learning approach: In the lecture based class students used the anthropometric tables to determine proper design for a particular population. With the active learning exercise, students actually took measurements of their classmates stature and developed the data tables for particular populations so that they could better understand where the data came from and how it was developed.

Active Learning Exercise #2: NIOSH Lifting guide problem

> Objective: Apply the NIOSH lifting equation in order to determine manual material handling limits for a task, evaluate the working conditions and suggest reasonable solutions for the situations.
>
> Lecture vs. Active learning approach: In the lecture based class students determined risks for lifts based on reading word problems, determining which factors where which and then applying them to the NIOSH lifting equation. With the active learning exercise, students actually performed a lift while their partners measured each factor to figure out which factor was which for the equation.

Based on results after one semester of active learning implementation, it appeared that test scores associated with these particular topic areas improved. These changes were documented via the standard curriculum update form used by the engineering technology faculty for assessing each course.

After two years of offering this course as lecture-based with only the two previously noted active learning exercises to enhance student learning, it was noted that more active learning exercises were needed. The problem was how to fit them into the already full lecture-based course. This problem highlighted the same issue that brought about the flipped classroom approach, how to make time available in the classroom. In 2006, a change was made to the introductory ergonomics course to open class time by changing the lectures from traditional chalkboard lectures to power point lectures. Like the flipped classroom, it was found that classroom time could be opened up for other purposes with the addition of technology in the classroom. In this case, the power point lectures freed up time that students were previously using to take notes. Today there is no reason for students to copy multiple formulas and long explanations when they are readily available and accessible through technology.

After a few years the course was again restructured to gain additional in-class time by changing from a 3-hour lecture only course to a 2-hour lecture and 2-hour lab course. The addition of power point lectures to free up note-taking time along with adding an extra hour of lab time, allowed for more active learning time. Additional labs and several in-class exercises and demonstrations were developed to allow the students to experience additional concepts rather than simply solve book problems.

This course is one of the well-documented accounts of how active learning components have been added to engineering technology courses at Purdue University Northwest. These active learning components provide an alternative learning approach for knowledge that is often difficult to understand through a purely textbook and lecture-based classroom approach.

Active Learning Exercises Implementation: Example 2

A second example of a traditional engineering technology course that utilized active learning techniques at Purdue University Northwest is a senior level course, Computer Integrated Design and Manufacturing, MET46100. This course was started in 1998 as the result of an NSF grant that provided a CNC Machining Center and a 3D printer for student use. The course description and objectives follow:

Course Description:

A combination of lecture and laboratory projects demonstrating all phases of a products life cycle from conception through recycling. Laboratory projects include designing parts, graphical finite element analysis, rapid prototyping, computer controlled manufacturing, and testing all using a common, three-dimensional graphical database.

Course Objectives:

At the completion of the course, the student should be able to:

- explain the use and applications of parametric design

- explain the use and applications of finite element analysis (FEA)

- use parametric design and FEA to design and analyze mechanical components in an experiential learning environment

At the time the course was initially developed, solid modeling was not widely available. The course initially used ProEngineer software since modeling, analysis, and CNC programming were all available within ProE. Much of the semester was used for learning solid modeling followed by some simple FEA, a chain link design project, followed by 3D printing and CNC machining of the link. The course started as an active learning course with short lectures followed by assignments. The instructor then went around the room answering questions while the students performed the assignments.

The introduction of this course coincided with ABET's ET2K accreditation change to outcomes based assessment. The course has a consistent history of assessment data since 2002 using a format similar to Figures 1 and 2. In the 20 year history of the course, much has been learned about teaching design with open ended projects and active learning. For example, as early as the Fall 2002 semester, the instructor's assessment comments included reducing lecture and encouraging more active learning. Also note this method showed success based on student evaluations.

By 2010, solid modeling was widely available, and the students were learning it in their introductory CAD courses. Hence, the course software changed to Solidworks and the emphasis of the class changed as well. This was documented in the course assessment files. Since the students already knew Solidworks from previous course work, the course emphasis changed to more design projects moving more towards active learning.

At the current time, the course uses three open ended design projects with more recent projects including 3D printed and machined aluminum drones, machined aluminum 4 wheel rovers, 3D printed 6 wheel rovers, and combined aluminum/printed 6 wheel rovers. Lectures are kept to a minimum, and students actively solve the assignments and design projects. Collaboration between student groups is encouraged, and course assessments show high student satisfaction with this course. Fig. 3 shows the most recent course assessment comments.

<table>
<tr><td colspan="4" align="center">MET46100 Instructor Update Information</td></tr>
<tr><td colspan="2">Date Submitted: 12-10-17</td><td colspan="2">Date to be Reviewed: 1-8-18</td></tr>
<tr><td colspan="4">Responsible faculty for the review: Higley</td></tr>
<tr><td colspan="4" align="center">Type of Update</td></tr>
<tr><td>☐ New Edition of the Text</td><td>☐ New Text Adopted</td><td>☐ New Software</td><td>☑ Teaching Method</td></tr>
<tr><td>☐ New Laboratory Equipment</td><td>☐ Lab Material Update</td><td>☐ Teaching Initiative</td><td>☐ Other</td></tr>
<tr><td colspan="4">Description of Condition Prior to / After Update:</td></tr>
<tr><td colspan="4">The rover with 3D printing helped this to be a very successful class.</td></tr>
<tr><td colspan="4">Assessment Method Used to Evaluate Short or Long Term Results:</td></tr>
<tr><td colspan="4"></td></tr>
</table>

Fig. 3
Instructor Summary of course
Fall, 2017 MET46100

In the 20 years of MET46100's existence teaching pedagogy became more refined, it is easy to see this has been an active learning course since its introduction, and course assessment data and anecdotal data from graduates show this is a very effective way to teach mechanical design. To change this course to a flipped classroom approach simply because it is the latest trend would not serve any purpose. Active learning is already at the foundation of the course design so there is no need to convert it to a flipped approach.

## Conclusion

Flipped classrooms propose to answer the call for reforming traditional higher education teaching to pave the way for student-centered active learning strategies [5]. But, flipping a class is only one method to bring hands-on learning activities to the students. DeLonzier and Rhodes concluded from their research that the important aspect that flipping the classroom attempts to achieve is freeing up time for active learning in the classroom. But this is only one method and others should not be ignored [3]. Engineering technology programs have been utilizing active learning techniques for many years. The flipped pedagogy is only recently more feasible with the advent of new technology for learning making it the "new method" to try. Programs that have traditionally focused on theoretical aspects of their profession are now realizing that they can free up time in the classroom by allowing students to learn the theoretical concepts at their leisure while bringing the concepts to life during classroom time. Thus, the flipped classroom approach provides a framework for designing educational opportunities that engage students in active and applied learning [1].

As Turner and Webster highlighted in their evaluation of a flipped course in electrical engineering technology, the ultimate goal of any engineering technology program is to produce students who can solve open-ended problems and who can apply the technical knowledge gained in the classroom to a wide variety of real-world situations [7]. So while flipping a class is one method to create free time to engage students in active learning, it is not the only way. The need for changing to a flipped pedagogical approach should be evaluated prior to changing just because it is "the new method" to teach. As the examples shown in this paper suggest, many engineering technology courses have historically implemented active learning classroom components without the need for flipping their classes.

When an instructor has already designed their courses with active learning components, trying to then implement the flipped approach will require consideration of how it will enhance the student learning process. As this instructor found, when an instructor's approach to teaching already incorporates active learning methods, flipping the class may not enhance the student learning process for all students even when the new approach follows proven step-by-step methods. Implementing a flipped classroom approach should be considered when an instructor is attempting to free up time for more active learning opportunities. It is more complex than simply recording lectures, changing syllabi and adding incentives for students to take ownership of their learning process, the flipped approach can be confusing and very time consuming for many students who prefer a more traditional approach to learning.

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