FLIPPING THE ENGINEERING CLASSROOM

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Abstract – Traditional classrooms encourage surface and strategic learning instead of the deep learning required for true mastery of one's discipline. By challenging beliefs in the tried-and-true roles of professor and student, a flipped classroom can increase student accountability, engage them in a dynamic learning environment, and improve their depth of learning.

Keywords: flipped learning, student engagement, authentic learning, peer supported learning, graduate attributes, deep learning, active learning, retention of knowledge.

1. INTRODUCTION

Traditional teacher-centered, lecture-based delivery encourages surface and strategic learning instead of the deep learning required for true mastery of one's discipline. One alternative to this approach is flipped learning, a methodology that is rapidly finding its way into higher education. Many academics differentiate traditional and flipped classrooms by when and where instruction is delivered, with traditional delivery presenting content in the classroom with assigned work done at home, whereas flipped delivery has content available digitally for students to view outside the classroom, and assigned work being done during scheduled class time. But simply flipping the where and when of delivery and homework does little to address the problems associated with deep learning and mastery. This paper discusses the findings of a preliminary study in flipped learning that demonstrates increased student engagement, improved student accountability, and improved depth of learning.

2. BACKGROUND

2.1. Student Engagement

Student engagement is generally accepted to be the degree to which students participate, are interested in, and are motivated by their learning or instruction. Washer and Mojkowski, as shown in Fig. 1, identify ten expectations

that students have of school, each of which helps form the basis of a student-centered and engaging learning environment.

Fig. 1. Student Expectations of School

The results of a 2010 survey of more than 42,000 high school students^[11] confirm these expectations showing that only 25% were engaged when listening to a lecture, compared to almost 60% who indicated that they are engaged when doing projects or participating in discussion or debate. It is apparent that students will, when appropriately challenged with authentic and relevant applications, be active and engaged in their own learning.

2.2. Deep Learning

In his guide *Learning and Teaching Theory for Engineering Academics*, Houghton defines deep learning as “the critical analysis of new ideas, linking them to already known concepts and principles, and leads to understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts.”^[5] He continues, “over reliance on traditional lectures, where students are passively taking notes and not being required to engage actively with material, will not encourage a deep approach.” On the other hand, structuring the learning environment so that students explore and link key concepts to solve authentic problems produces graduates who truly understand the discipline vs. those who cannot differentiate the principles and processes from the examples.

2.3. Flipped Learning

Although flipped learning has been a part of the educational system for decades, Aaron Sams and Jonathan Bergmann^[1], two high school chemistry teachers from Colorado, are considered to be the pioneers of the modern movement. Starting in 2007 with what they call Flipped Class 101, students watched content-specific videos at home and used what had previously been lecture time for doing homework. Sams and Bergmann's goal was to maximize face to face time in the classroom. This process evolved into what is now known as Flipped Mastery 201 where the focus is on deeper learning strategies and mastery of the discipline, and where students are accountable for their own learning. Sams and Bennett^[8] said it best: "Ultimately, flipped learning is not about flipping the "when and where" instruction is delivered; it's about flipping the attention away from the teacher and toward the learner."

There are two main flipped learning models, the first of which is loosely based on Karplus' learning cycle of exploration, concept development, and application as described in Sunal's *The Learning Cycle*^[9]. The *Explore-Explain-Apply* (EEA) model provides students with their first exposure to content during guided exploration in class. This is followed by an explanation of key concepts outside of class, and finally the interactive application of concepts in class. The second flipped learning model, *Prepare-Apply-Confirm* (PAC), is a slight variation where students have their first exposure to content outside of class. Class time involves an interactive application of concepts, followed by a review and confirmation of the new knowledge and skills outside of class. In both models the learning outside of class is supported by learning resources such as video (instructor generated or existing), interactive modules, Massively Open Online Course (MOOC) materials, text books, or journal articles.

3. PROCESS

A study of flipped learning was conducted by the author over two academic year 2012-13 and 2013-14 involving two cohorts of first year Electronic Systems engineering (ESE) students at Conestoga College Institute of Technology and Advanced Learning. The ESE program uses a Project-Based Learning (PBL) model with projects designed to cross course and discipline boundaries.^[6] Students complete two to three authentic, level-appropriate projects each term. The specific course for the flipped learning study is a two part introductory Digital Electronics class delivered over the fall and winter terms.

The study set out to determine whether flipped learning would:

- i. improve student engagement by using a dynamic,

interactive learning environment

- ii. increase students' accountability for their own learning by using peer-supported learning
- iii. improve students' depth of learning by using authentic and relevant applications

3.1 Learning Environment

This two part digital electronics course covered the standard topics including combinational and sequential logic, MSI level building blocks as well as an introduction to microprocessor systems. Similar to the ideas presented by Nisan and Schockenin in *The Elements of Computing Systems*^[7], authenticity was provided by focusing the topics on the progression from NAND gate to microprocessor, with each component explored and built upon.

The PAC model of flipped learning was chosen for this study. Prior to each class session, students were required to watch two to four short, focused videos prepared by the professor. Each video, five to fifteen minutes long, either summarized a key concept or provided worked examples. Each set of videos covered the material that was previously delivered by lecture. Slides and/or scaffolding sheets were provided to help guide and focus the students' learning as they viewed each video.

Class time was scheduled in three hour blocks. Each block began with an entry activity that cognitively prepared each individual student for the day's application of the key concepts. This entry activity generally took the form of a self-marked quiz that captured the essence of the content presented in the videos. Students were encouraged to attempt the problems without using any resources, but were free to access them as required. Upon completion, randomly selected students presented their solutions to the class for discussion. This was followed by a peer-supported exploration or application of the key concepts. Students were placed in randomly selected groups (different each class) of three to four students and challenged to investigate, analyze, or design various digital elements related to the session's focus. Once or twice during the session, groups were randomly selected to present their work to the class for discussion. Each class finished with a graded exit activity, normally an analysis or design problem where individual students were required to demonstrate their level of mastery of the session's content.

Students confirm that they have acquired these new concepts by applying them in one of the semester's integrated projects such as investigating the health effects of magnetic fields using a self-designed field meter.

3.3 Procedure

For the purposes of this flipped learning study, student engagement was measured using an online student survey administered at the beginning of the second part of the digital electronics course. Students were asked to respond to four questions:

- i. What could the teacher have done differently or better?
- ii. What would you like the teacher to do more of?
- iii. What would you like the teacher to do less of?
- iv. What could you have done differently or better?

Student accountability was measured informally by the level of in-class participation and the quality of the material presented for classroom discussion. Process was emphasized, with students required to fully document their solution, enunciate their thinking, justify their choices, and respond to clarification questions.

Emphasis of this study was placed on measuring the change in students' depth of learning by tracking grades on midterms, final exams, and the semester's integrated project.

Questions on midterms and final exams were classified according to the levels of Bloom's cognitive domain taxonomy. Each was identified as falling into one of the following categories:

- i. Knowledge and Comprehension (K&C)
- ii. Application and Analysis (A&A)
- iii. Integration and Synthesis (I&S)

The average raw grades were collected for each category over a two year period. The first year was a traditional delivery, while the second was flipped. It was assumed that in the flipped learning cohort, there would be an increase in the average grades in the I&S category.

4. RESULTS

4.1 Student Engagement

Feedback from the online student survey indicates that they appreciate and are engaged by flipped learning. Responses such as "I prefer this style of class to traditional lectures. I find that I am getting more out of these classes.", "I would like the teacher to continue splitting us up in groups and after the 'investigation' is over, the class comes to a consensus of the topics being taught", and "I like how the teach [sic] is getting us more involved, it make [sic] the class understand better, and if any questions arise they can be answered easier." indicate they feel they are learning from the interactive peer-supported environment. There was not a single response that suggested a return to the traditional way of delivery.

Students also seem to appreciate the accessibility and usefulness of the videos. Comments like "I also like how

the videos are in depth, and the fact that the lessons are easy to access. That means if a student misses class, they can easily understand the topic of study. The student can also repeat the video for better clarification [sic] and reminders.", "continue on at the same pace and method of instruction", and "the way the lessons cater to multiple learning styles is impressive." indicate a willingness to learn outside of a traditional classroom.

4.2 Student Accountability

Students actively participated in each class. It is expected that this is because of two things: the time available to complete the task did not provide opportunity for much diversion, and groups were randomly selected to present their solution. In many cases, students voluntarily continued their work on the task well past the end of the scheduled class.

Flipped learning also allowed more reserved students an opportunity to be equal participants in the class. Responses are no longer dominated by a few keen students, but equally shared across the student group.

Students indicated they were comfortable asking for assistance as they worked through the assigned task in class. "... and if any questions arise they can be answered easier." Knowing they may be selected to present their work helped ensure that they clearly documented their thought process as they worked through the task. They regularly questioned each other as they worked toward a solution so that each student in the group could respond to questions from their peers during the classroom discussion.

Students also seem to recognize the value of the peer discussion that followed the investigation, analysis, or design activity, stating "When the groups were presenting at the front of the class, I could have taken notes about more complex things that I am not likely to remember in the future."

4.2 Depth of Learning

The average midterm and final exam grades in each of the Knowledge and Comprehension, Application and Analysis, and Integration and Synthesis categories were analyzed.

Table 1, with results from the fall term, shows that the average raw scores on midterms and final exams increased anywhere from 7% to 22% in all categories except A&A which decreased by 10%. Overall though, in the two categories that involve the higher order cognitive skills (A&A and I&S) that correspond directly to an increased depth of learning, average raw skills rose 3%.

Table 1: Average Fall Exam Scores categorized by Cognitive Level of Assessment

Table 2 shows the results for exams in the winter term that were available up to the date of publication. Average raw scores on the midterm rose anywhere from 6% to 23%, with an overall increase of 28% in the two categories (A&A and I&S) related to an increased depth of learning. This significant change in results from the fall to the winter of the course may be a result of increased comfort level with the flipped learning methodology.

Table 2: Average Winter Exam Scores categorized by Cognitive Level of Assessment

The change in distribution of grades from traditional delivery to flipped learning was also analyzed. A comparison of results from the fall midterms is shown in Table 3 where flipped learning produced a more normalized grade distribution.

Table 3: Distribution of Grades – Fall Midterm

Table 4 compares the distribution of final exam grades. While a higher percentage of students did very well, the students who achieved grades around 50%, did not show

immediate improvement from the flipped learning environment.

Table 4: Distribution of Grades – Fall Final

Table 5 shows the midterm results for the winter term. Average grades shifted significantly as students became more familiar and comfortable with the flipped learning environment.

Table 5: Distribution of Grades – Winter Midterm

Within the program's PBL environment, students are expected to transfer and apply the knowledge and skills learned in courses to following projects. Table 6 shows a significant improvement in the application of this knowledge from the traditional implementation to flipped learning.

Table 6: Distribution of Grades – Field Meter Project

5. DISCUSSION

The results of this study appear to confirm that flipped learning improves student engagement and increases

student accountability. Students actively participate in each class, contribute to the learning of their peers, and appear to be more focused in their learning. Their comments indicate that they appreciate the opportunity to take control of their own learning, and prefer flipped learning to the traditional classroom.

As students become more comfortable with the flipped methodology, their depth of learning appears to improve. More students achieve higher grades in the categories associated with the higher order cognitive skills of application, analysis, integration and synthesis. Their overall performance also improves in their ability to integrate content-specific knowledge and skills into cross course and discipline projects.

While a traditional classroom centers around the required knowledge base, flipped learning provides an opportunity to focus on the process required to analyze, investigate, design, demonstrate, and communicate that knowledge within a guided environment. Students also learn to explain and defend their thinking process. Very early on they grasp the concept of metalearning. They realize that being aware of what they know and how they learn, means that they can take control of their own learning.

6. FUTURE WORK

Evaluation of this flipped learning model will continue. Next steps include an evaluation of whether the increased depth of knowledge translates to better retention of knowledge. The current model will also undergo further assessment to assure that its effectiveness is independent of the students in the specific cohorts used in this study.

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