IMPLEMENTATION OF A BLENDED INSTRUCTION-BASED & PROBLEM-BASED LEARNING STRATEGY IN A SECOND-YEAR ENGINEERING CURRICULUM

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Abstract – This paper presents the implementation of a blended Instruction-Based Learning /Problem Based Learning (IBL/PBL) approach in an engineering technology curriculum. In a second year course "Thermodynamics and Heat Transfer", students' background knowledge is developed through IBL in the form of weekly lectures, and PBL in the form of labs and project. Eight weekly lab experiments are used to develop the students' lab skills. Each one of the labs is scheduled such that it perfectly matches the material covered in the lectures. Through such a coordinated blended approach, students see in real-life how analytical solutions discussed in the textbook are applied and what the effect of altering design parameters is. This helps them develop problem solving skills. Also, they collect and analyze data to understand the limitations of the theory. Then in weeks 9-12, a PBL course project is introduced allowing students to implement the knowledge learned. In groups, they research the given topic, brainstorm solutions, build and test the prototypes, and present the results to the class. The benefits of such a blended approach include greater emphasis on important concepts, easier visualization of abstract ideas, higher adaptation of delivery method to the course content, broader scope of expected learning outcomes and increased student/professor contact time.

Keywords: Instruction-Based Learning, Problem-Based Learning and Blended Learning.

1. INTRODUCTION

Traditional engineering education uses lectures to provide Instructional Based Learning (IBL) opportunities for instructions to be delivered by a professor to the students. It is well known that students learn in different ways. Some students learn better by reasoning, some by doing and some by problem solving. In the past, when class sizes were smaller, interactions between professor and students were easier, and professors could pay more attentions to students' individual learning needs. Today, due to large class sizes, it is very difficult for professors to address the need for different learning styles. The effectiveness of using the IBL method alone is questionable.

Problem Based Learning (PBL) uses open-ended problems to help students learn by solving real-world problems. Typically PBL is implemented as follows [1].

Students will work in groups and first define the problems at hand. Then they evaluate what they know and what they don't know, do research and find more information, meet with facilitator every week to seek feedback, and present solution in a final report.

Blended IBL & PBL is an approach which uses both IBL and PBL in a single course. It provides learning opportunity in multiple teaching styles. Depending on the learning style of the students, they could benefit from either the IBL or the PBL part or both. Information is presented to the students multiple times in different ways making it easier for the material to "sink in" and "mental models" to build up in the students' minds. [2] The PBL part provides a platform for the students to apply the theories studied earlier in the IBL part of the course. This will instill confidence on the students and could lead to application of the experience to more complex problems in the future.

AUTOTECH 2TS3 – Thermodynamics & Heat Transfer is a second year course in a 4 year engineering technology program at McMaster University's School of Engineering Technology. Traditionally, Heat Transfer and Thermodynamics are considered by the students to be very theoretical due to the heavy mathematical calculations involved. This paper presents the methods used and the lessons learned in the implementation of a blended IBL/PBL approach in teaching this course.

2. BLENDED IBL & PBL IMPLEMENTATION

2.1. Organization of the Course

In Winter 2014/2015, there were 51 students in the AUTOTECH 2TS3 – Thermodynamics & Heat Transfer

course. Students go to lectures 2 times a week in a lecture room, and they were divided in to 4 lab sessions (with roughly 12 - 14 students per session). The students were asked to work in a lab group with another student. Each week, there were 3 hours of lectures and 3 hours of labs. One lecture instructor and one lab instructor (each with a doctoral degree in engineering), were responsible for the course.

During the 12 weeks instructional period within the term, lectures were delivered using the IBL approach; while the labs were delivered using the PBL approach. The students were informed at the beginning of the term that 8 weeks of the lab time would be dedicated to develop students' basic lab skills. The last 4 weeks of the lab time would be used for an open ended project. The students would pick a heat transfer topic not covered by any of the existing 8 experiments, based on theories studied in the course, build a hardware prototype, design a lab experiment, calculate and predict the outcome of the experiment. The student would also test the prototype developed to verify the theoretical prediction. Finally, a presentation of the results to the rest of the class and a project report is required. The 8 labs with 8 reports submitted were worth 20% and the final project was worth 10% of the final grade.

2.2. Blended Approach Benefit #1: Greater Emphasis of Important Concepts

The PBL experiments highlighted important concepts that were not obvious in the IBL part of the course. For example, the effect of contact resistance in heat transfer was first covered in the lectures and then it was studied further in one of the PBL labs. By comparing two identical aluminum specimen heating on a hot plate, one with a few drops of engine oil added in the interface and one without, students were able to experience first-hand how engine oil reduced the contact resistance allowing the specimen with oil to heat up much faster.



Figure 1: Contact Resistance Experiment

When the students were asked to explain the results, they discovered through research that oil is a better conductor than air and filling the air gap between a heat source and a heat sink would improve the heat transfer.

2.3. Blended Approach Benefit #2: Better Visualization of Abstract Ideas

Another important benefit of the blended approach is that the students can visualize abstract ideas better. For example, the ideas of "fin parameter, m" and "convective heat transfer coefficient, h" are very abstract if it were covered in IBL lectures only. After a PBL lab experiment like the one shown in Figure 2 below, the students measured the temperature distribution along a fin and plotted the data to obtain the fin parameter, m, and subsequently calculated the convective heat transfer coefficient, h. [3] This exercise allowed the students to visualize these abstract ideas much more effectively.



Figure 2: Visualization of the Fin Parameter Concept

2.4 Blended Approach Benefit #3: Higher Adaptation of Delivery Method to the Course Content

Some course topics can be delivered more effectively using an IBL approach while other topics are better off delivered using PBL. A blended IBL/PBL approach allows the ratio of IBL and PBL to be customized based on the course content. For example, the Thermodynamics & Heat Transfer course discussed so far has been using a 70% IBL and 30% PBL based on the amount of course marks assigned to each of the two styles of learning method.

In another second year course AUTOTECH 2AC3 -Advanced CAD in the same program, a blended IBL and PBL approach is used with a heavier 60% weight on the PBL part through two major projects on design and modelling. The modeling and design principles are first taught in an instructional format. With classes taking place in a computer lab, the students are asked to practice the theories discussed right on the spot. A 40% weight is placed on the IBL part of the course through in class submissions and a final exam.

Depending on the course contents, the learning style of the students and the expected learning outcome, the instructor can easily adjust these percentages to tailor to the course.

2.5 Blended Approach Benefit 4: Broader Scope of Expected Learning Outcome

Expected learning outcomes are the knowledge that the students are anticipated to obtain when they have taken a course. The blended approach allows the expected learning outcomes of a course to be broadened. The School of Engineering Technology at McMaster takes a more practical approach to students' education. In this course, Heat Transfer & Thermodynamics, there are 3 expected learning outcomes that would have been impossible to achieve if this course were not executed using the blended approach.

(1) Perform experimental measurements and observations on heat transfer and thermodynamics systems and report on experimental findings while comparing to theoretical predictions.

(2) Design, build and test a system for energy recovery in a vehicle or home application.

(3) Combine convection and conduction principles for the sizing and designing of shell-and-tube heat exchangers.



Figure 3: Shell and Tube Heat Exchanger Experiment

2.6 Blended Approach Benefit #5: Increased Student/Professor Contact Time

The final and the most obvious benefit of the blended approach is that student/professor contact time is

increased. Increasing contact time allows the professor to get to know the students better – including how they learn best, which part of the course they like the most, what concepts they are struggling with and what school projects they are busy with. This is all very important information for a professor to know in order to make fine adjustments to the delivery of a course.

To ensure the quality of the teaching, McMaster University's Automotive and Vehicle Technology Program employed full time professors (not part time graduate students) to teach both the IBL and PBL part of each of the courses. The professor responsible for teaching the IBL part of the course has a doctoral degree in Chemical Engineering while the PBL professor has a Ph.D. in Mechanical Engineering.

In the Thermodynamics & Heat Transfer course, due to the blended IBL/PBL approach, the student/professor contact time per week is 6 hours. This is a 100% increase in contact time as compared to a course executed using the traditional IBL approach alone.

3. CHALLENGES AND METHODS TO OVERCOME

3.1 Challenge #1 – Cost

The first challenge for using the blended approach is the added cost due to the need for extra instructor and equipment in the lab. Also, the space required for equipment storage could add to the cost as well. One approach taken to reduce the cost of running this course is that smaller scale equipment is used.



Figure 4: Small Scale Radiators Used for PBL

3.2 Challenge #2 – Coordination of Instructors

It is agreed by the IBL/ lecture and PBL/lab instructors that the topics of the experiment will align with lecture

topics within a week. It is believed that if the IBL and PBL part of the learning can be totally blended together, the knowledge will form a stronger "mental model" in the student's mind. [4] The lecture and lab instructors met once per week during the whole school term to ensure that the plan is executed precisely.

3.3 Challenge #3 – Not So Hands-on Students

In weeks 9-12 of the PBL part of the course, the students were asked to design and build a set of equipment to study a topic that is not covered in the first 8 weeks of experiments. To address the issue that some students were not very good at building lab equipment, they were allowed to "borrow" existing equipment from the lab. As long as the topic selected was not fully investigated in any one of the 8 lab experiments before, they were allowed to modify the equipment to investigate further. This way, nobody would feel left out from the PBL part of the course.

3.4 Challenge #4 – Too Much Work for the Students

Since there are 3 hours of PBL lab time required in this course, in comparison to traditional courses with only IBL component, the time commitment from the each of the students is increased. In average, students take 6 courses per school term in our program at McMaster. If all 6 courses are executed with the blended IBL and PBL approach, the students could be overloaded very easily. It is important that the department chair is managing the teaching approach of all its courses to avoid such a problem.

4. CONCLUSIONS & RECOMMENDATIONS

The 8 weeks of lab experiments prepared the students very well for the open ended project at the end of the term. After following the lab manuals for 8 weeks, the students already learned their way around the lab. This could be a useful method to provide initial guidance to students for other project courses.

Although some students did not like the course project at the beginning due to the slightly open-ended nature of the project, with the guidance of the PBL instructor, the students learned to adapt to the need for their creativity and endurance.

There were other course projects due at the end of the school term. The course project in this course was no doubt competing with other course projects for students' time. One recommendation is to encourage students to start thinking about the project earlier in the school term and not to wait until the end of the term.

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