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A case study on intentional learning in engineering and technology education

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ABSTRACT: A case study on intentional learning in core engineering courses is presented in this article. The same instructor and group of students in different courses are compared. The two courses, while at a similar level of technical difficulty, were delivered using different teaching methods: one with traditional delivery and one with more elements of intentional learning. Apart from regular evaluations and student feedback, small group analyses were also used to compare various aspects of the teaching and learning experience. It was confirmed from the study that the students were more receptive to the teaching methods that incorporate intentional learning elements. Student perception of learning also scored higher for the teaching method that implemented more intentional learning elements. A clear correlation was also found between students' classroom activeness and the final grades, when more intentional learning elements were employed. Such correlation tended to disappear with the traditional teaching.

INTRODUCTION

Intentional learning refers to cognitive processes in which students take ownership of their own learning. This is represented but not limited to the following aspects: 1) the students set their own learning objectives; 2) the students monitor their own progress toward their learning goals; 3) the students pay attention to and look out for the conditions and environment in which they learn best, and 4) the students actively make connections and add meaning to their learning [1][2]. It is well recognised that the most successful and accomplished learners are intentional learners. The benefit of such intentional learning experience and habit is often life-long rather than short-lived during the college years. However, intentional learning does not come naturally to students. In addition, in many professional areas, especially in engineering and engineering technology education, intentional learning is also foreign to instructors.

Traditionally, engineering and engineering technology education is a more passive process for the student, with the knowledge and skills *being taught and transferred* from generation to generation. Apprentices do not need to, and rarely have, a global picture of their learning objectives. They often more passively rely on masters and teachers to set their goals and monitor their progress. Apprentices also depend on masters and teachers to make the connections and add real-world meaning to their learning, and often the taught connections by masters are so lofty and remote to them that only after many years of practice may the students make the link and finally understand the meaning.

It is, therefore, a great challenge for engineering and engineering technology educators, as well as for the students to be helped to become more intentional learners, which will benefit them in their life-long self-directed professional careers after college. A case study is presented in this article, where the same instructor and the same group of students in two similar-level technical electives in the upper-level core electrical engineering sequence are compared; one with more traditional instruction delivery and assessment and one with more elements of intentional learning [3-5]. Apart from the standard course assessments and student feedback, such as the Student Assessment of Instruction (SAI), small group analyses were conducted and from the results comparisons were made between the various aspects of the teaching and learning experience, such as teaching effectiveness and student experience.

DESIGN OF EXPERIMENT

As is common in other Scholarship of Teaching and Learning (SoTL) projects, the students are the human subjects of the study. Accordingly, the researchers applied for and secured approval from the Human Subjects Institutional Review Board (IRB). In implementing the IRB procedure, the researchers secured the signed student *informed consent statements* close to the end of the semester. The timing of disclosing the informed consent statements was chosen carefully to minimise the potential bias in student assessments and feedback. A sample informed consent statement is exhibited in the Appendix.

The IRB process is a very helpful one because there are many common subtleties involving the design of study in SoTL projects. These issues often are foreign to professors and lecturers in engineering and engineering technology areas who, generally, do not have formal training in their professional backgrounds in dealing with human subjects. Apart from the issue of human subjects, some of the subtleties are unique to SoTL projects. For example, when teaching effectiveness is evaluated by comparing two different teaching methods, as it was in the study presented here, as well as other studies published previously, the design of the study should ensure that no group of students receives preferential treatment.

As typically is the case in such SoTL projects, the new teaching method is evaluated against a control group in which the normal teaching method is applied. In such cases, the investigator should ensure that the new teaching method does not impair student learning. This task usually is more difficult than it appears to be because the effectiveness of the new teaching method is the very subject of investigation. The investigators need to make sure that the potential benefit of the study significantly exceeds the risk of learning disadvantage. On the technical side, ideally, such a study would deliver the same content to the same group of students with the same level of previous knowledge using different teaching methods, and the teaching effectiveness would then be compared. However, this obviously is impossible in practice. Most SoTL studies are conducted in the due course of normal teaching and learning processes. The implication of such inherent impairments imposed on SoTL studies has to be carefully addressed because, in many cases, it will limit the generality of the research results.

In this study, the researchers endeavoured to compare the teaching and learning effectiveness of two different teaching methods in the core engineering and engineering technology curriculum. The control group used the traditional content delivery method, where the teacher specifies the learning objectives and the evaluation methods. The content was delivered mostly in traditional lecture form assisted by available multimedia tools, such as PowerPoint presentations. The new teaching method being evaluated was designed according to intentional learning principles and utilised several intentional learning tools, such as a *jigsaw puzzle* type of group discussion and role playing. The students also were given the opportunity to define their learning objectives and choose the evaluation methods. In both study and control cases, the same instructor taught the same group of students during the same semester. The students came to the two classes involved in the study with the same prior knowledge.

The students attending Course A and Course B (control) were invited to participate in the study. The two courses are at a similar technical level and of the same general topic area of modern optics and optoelectronics. However, they have different focuses and inherently are different in course content. Course A serves a purpose of broad survey of modern optical engineering technologies, with the review of fundamentals of wave optics. Course B is more focused on a single topic. It is arguable that Course A is more amenable to a group discussion, role playing (experts at different topics) and *jigsaw puzzle* forms of intentional learning tools. Course B is more involved in terms of design principles and depth of the topic, and arguably is more suitable for a traditional lecture and paper exam type of teaching.

The design of the study was in concordance with a normal course. A prerequisite met by the study to obtain IRB approval was that it would not pose any perceivable risk of psychic, legal, physical or social harm. The study also posed a low educational outcome risk in that essentially different technical materials were presented in a more suitable way, as the investigators saw fit. The potential benefits actually included both better understanding and better learning outcomes for the participating students, as well as benefits to the general engineering and engineering technology education community. While such design of the proposed study minimised the risk of learning deficiency, it should be noted that the implications of the comparison results also need to be taken into consideration.

The data points collected for this study included traditional ones, such as test and exam scores, and classroom discussion participation. The students were also invited to participate in data collection of the standard SAI course evaluation as a routine university-wide survey, as well as targeted small group analysis (SGA) sessions. Sample questions in the SAI assessment tool are shown in Figure 1.

The SAI contains both the standardised response, on a scale from 1 to 4 (Figure 1), as well as open-ended questions. Each course in the study was given its own survey with the same questionnaire. The other assessment tool, the SGA analysis, ran two common sessions for both courses in the study: one at the beginning of the semester and one at the end of the semester. Questions were targeted to evaluate teaching effectiveness and student perception of the teaching. Sample questions included: *What aspects of this course and/or the instruction are helping you learn? What aspects of this course and/or the instruction would you recommend be changed to improve your learning?*, and, for the follow-up session: *What aspects of this course and/or the instruction have been changed to improve your learning?* and *Are there aspects of this course and/or the instruction that are impacting your learning in a negative way?*

DATA ANALYSIS AND ASSESSMENT RESULTS

Table 1 summarises the final grades categorised by the course participation level assigned by the instructor according to the activeness of each student in classroom participation, such as asking questions, feedback and leading the discussions, etc. It is noted that while in Course A all students were more involved in classroom discussion by requirement, it was roughly the same group of students who were more active than the other in both courses.

Student Assessment of Instruction: Standard Course Form

Organization and Clarity

My instructor is well prepared for class meetings.
My instructor explains the subject matter clearly.
My instructor clearly communicates course goals and objectives.
My instructor answers questions appropriately.

Enthusiasm and Intellectual Stimulation

My instructor is enthusiastic about teaching this course.
My instructor presents the subject in an interesting manner.
My instructor stimulates my thinking.
My instructor motivates me to do my best work.

Rapport and Respect

My instructor helps students sufficiently with course-related issues.
My instructor is regularly available for consultation.
My instructor is impartial in dealing with students.
My instructor respects opinions different from his or her own.

Feedback and Accessibility

Assessment methods accurately assess what I have learned in this course.
Grades are assigned fairly.
The basis for assigning grades is clearly explained.
The instructor provides feedback on my progress in the course on a regular basis.

Student Perceptions of Learning

My instructor advances my knowledge of course content.
My instructor promotes my understanding of important conceptual themes.
My instructor enhances my capacity to communicate effectively about the course subject matter.
My instructor encourages me to value new viewpoints related to the course.

Figure 1: SAI questionnaire, standard course form used for both courses in the study.

Table 1: Final grades and group average points categorised by activeness of the students.

Level of student activeness	% of students	Course A		Course B (Control)	
		Minimum & Maximum Grade	Group Average Point	Minimum & Maximum Grade	Group Average Point
most active	27	B+, A	3.55	A-, A	3.89
active	18	B, A	3.50	B, A	3.5
less active	27	B, A-	3.33	B, A	3.67
inactive	27	B, B+	3.11	B+, A	3.67

It should be noted that the above data must be used carefully because many other factors can also play into the final grades. For example, it may not make too much sense to compare the absolute values of the quality points across the two courses. On average, the instructor believes there is no significant difference between the levels that the students achieved with respect to the course objectives. Also, the assessment of the student activeness level is more subjective than objective. Nonetheless, the data seem to suggest that in the course involving more intentional learning elements, there is a positive correlation between student activeness in the classroom and the final grades. However, in the more traditional passively delivered course with less intentional learning elements, student activeness in the classroom is not necessarily correlated with the final grades. The most active group stands out in both courses, while the less active groups did significantly better in Course B (control group) than in Course A.

Table 2 presents a summary of the SAI results for both courses. Due to the standardised nature of the SAI questionnaire, the scores are indeed comparable across both courses and the results are consistent. In assessment areas unrelated to the delivery method, namely S3 and S4, the instructor received the same scores. On the other hand, for those assessment areas closely related to the content delivery method, the instructor scored higher in Course B (Control) on both S1, Organisation and Clarity, and S2, Enthusiasm and Intellectual Stimulation, whereas the student perceptions of learning (S5) is actually higher for Course A than the control. This seems to suggest that, even with a deficiency in implementing such intentional learning methods as compared to the more traditional passive teaching that an instructor is more familiar with, the student perception of learning is still better for Course A than the control. The SAI questionnaire also incorporates two open-ended questions, Q1: *Describe the best aspects of this course* and Q2: *Describe changes that could be made to improve the course*. The response rate to each of these questions can be considered a rough gauge of the strength and weakness of the teaching. In this respect, Course A has a 64% response rate to Q1 and an 82% response rate to Q2. In comparison, Course B, the control, has only a 45% response rate to Q1 and a closer 54% response rate to Q2. The data reflect the uneasiness that the students had on the teaching of Course A. In comparison to the responses to the control Course B, the data seem to suggest that, while the students do like the new teaching method, there are also many areas that can be improved. Combining the numerical assessment data and the open-ended question response, the SAI data seem to suggest that the students did feel they were learning better in a more intentional learning environment.

Table 2: Summary SAI results for both courses.

SAI Assessment Area	Course A	Course B (Control)
S1: Organisation and Clarity	3.0	3.2
S2: Enthusiasm and Intellectual Stimulation	3.0	3.1
S3: Rapport and Respect	3.7	3.7
S4: Feedback and Accessibility	3.3	3.3
S5: Student Perceptions of Learning	3.2	3.1

In addition to SAI, two sessions of SGA were also conducted that were more specifically targeted on the student learning experiences. In both responses, the students largely embraced the new teaching method in Course A, with less than 10% of students expressing more willingness toward the teaching method of Course B. One student noted that Course A *is more interactive between students and* [the instructor] and that *in* [Course B (Control)] *I think we need to get away from having Power Points all the time.* Another student commented, with regards to Course A, that *the class is more involved now. I can tell that the instructor is trying to get the class more involved and participating more, and this really helps in learning the material.* Overall, students noted that in Course A, they were required to take more responsibility for learning the material, which was aiding in their learning and retention of the material.

OVERALL EDUCATION OUTCOME AND FEEDBACK

Since the students involved in the study were upper-level electrical engineering students, up to the date of this reporting, initial placement data and post-graduation feedback also have been collected. Overall, 60% of the students were accepted and enrolled in Master's degree programmes at the universities that include Georgia Tech, Purdue, North Carolina State University, UNC Charlotte, University of Dayton and Western Carolina University. Forty per cent of the students were employed at various local, as well as national, companies. Given the challenging economic environment of local and national businesses, this 100% placement rate testifies convincingly to the overall programme education outcome.

Initial post-graduate feedback directly from the students includes comments such as: *My professors at Western taught me not only the course material but also the critical thinking skills and problem solving logic that will help me to excel…* and *The electrical engineering program contains a lot of math and physics that prepares students for any graduate school, but the optical focus of Western's engineering program has given us a head start. Many of the topics we covered in classes, such as geometrical optics and Fourier transform, are the focus of classes I have to take my first year (in Master's program).*

DISCUSSION AND CONCLUSIONS

In terms of content delivery, the instructor was able to deliver more technical content in Course B (Control) than in Course A. This largely was due to the decreased student discussion involved in Course B, which then naturally included more lecturing time. While there were concerns from the students that the content delivery pace may have been too fast in Course B and the students largely felt more comfortable with the content delivery pace in Course A, it seemed to the instructor that there were no significant impairments to the level of students' understanding and absorption of the material in Course B as compared to Course A.

From previous discussion of the acquired data, it could be concluded that the students felt better and had better perceptions of learning in terms of teaching and learning efficiency, with the more conventional delivery method in Course B seeming to exceed that of the new teaching method implementing more intentional learning tools in teaching efficiency. However, it should be noted that this result can be biased due to the possibility that the instructor was more efficient in applying the traditional teaching method, than in applying the new teaching method involving more intentional learning elements.

In summary, the conclusion that can be comfortably drawn is that the students were more receptive to the teaching methods that incorporated intentional learning elements. Even with a deficiency in implementing such intentional learning methods, as compared to the more traditional passive teaching that an instructor is more familiar with, the student perception of learning still scored higher for the teaching method that implemented more intentional learning elements. There is also an interesting correlation between students' classroom activeness and the final grades, when more intentional learning elements were involved in teaching. Such correlation tended to disappear in the more traditional passive teaching.

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APPENDIX

Informed Consent Statement Form

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Principal Investigator (PI): Bill Yang, Ph.D., Phone: 828-227-2693
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Project Title: Intentional learning in core engineering and engineering technology education

<u>Purpose of Study:</u>

You are invited to participate with no obligation in a research study which has as its main purpose to describe the similarities and differences between a more traditional lecture based content delivery method and a more intentional learning amenable delivery method of core engineering courses at a similar level in undergraduate study.

<u>Description of Participation:</u>

The students attending EE425 Foundations of Optical Engineering and EE 465 Foundations of Laser Electronics will be invited to participate in the study. The two courses, although at a similar technical level, are inherently different in course contents. EE 425 serves a purpose of broad survey of modern optical engineering technologies with the review of fundamentals of wave optics. EE 465 is more focused on a single topic of lasers also with similar review of fundamental of wave optics. Accordingly EE 425 is more amenable to a group discussion, role playing (expert at different topics), and Jigsaw puzzle form of intentional learning tools. EE 465 is more involved in terms of design principles and the depth of the topic and is more suitable for a traditional lecture and paper exam type of teaching. The students are invited to participate in data collection such as SAI course evaluation and small group analysis. The questionnaires will take about 15 to 30 minutes to complete and will ask you questions regarding various aspects of the teaching and learning. These questionnaires will not be graded and data will be only available in summary form and no individual identity is accessible or revealed. We will have three small group analysis surveys and one SAI survey during the semester.

The proposed research is in concord with a normal course of teaching and improving teaching and learning. It does not pose any perceivable risk of psychic, legal, physical, or social harm. It also takes a low education outcome risk form that essentially different technical materials are presented in a more suitable approach as investigators see fit. The potential benefits include both better understanding and therefore better education outcome of the participating students as well as for the generations of engineering and engineering technology students at Western and at large as the investigators plan to share the result of the study with the general engineering and engineering technology education community.

Confidentiality:

Data collected by both SAI course evaluation and the small group analysis study are in summary form, no individual identity is accessible or revealed, the confidentiality of all subjects are maintained and all subjects are protected from the future potentially harmful use of the data collected. All data will be stored in the password protected university computers of the Principal Investigators.

Voluntary Participation:

Your participation is strictly voluntary. If you decide not to participate there will be no penalties or negative consequences. Your course grade or the way you are treated in this course will not be affected if you decide not to participate in this study. You may choose to withdraw from the study at any time and the Principal Investigator may choose to cancel your participation at any time. If you choose to withdraw, all data concerning you will be destroyed.

Do you have any questions? (Circle one) NO YES

If you circled YES, please contact the Principal Investigators, Dr. Bill Yang and/or Dr. Amy Martin at the above phone number or by email before signing this form. If you have questions or concerns regarding your rights as a research participant, you may also contact the chair of the WCU Institutional Review Board at 828-227-3177. Do not sign this form until these questions have been answered to your satisfaction.

YOU ARE MAKING A DECISION WHETHER OR NOT TO ALLOW THE PRINCIPAL INVESTIGATORS TO USE THE WORDS FROM YOUR QUESTIONNAIRES, INTERVIEWS, AND CLASS DEBATES FOR RESEARCH AND PRESENTATION PURPOSES ONLY. YOUR SIGNATURE BELOW ALSO INDICATES THAT YOU ARE OVER THE AGE OF 18.

I AGREE DO NOT AGREE (Circle one) to participate in this research study.

Participant's name (please print) ___________________ Date: _________________

Participant's Signature: ____