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The Effect of the Inverted Classroom Teaching Approach on Student/Faculty Interaction and Students' Self-Efficacy

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Introduction

For many years now, there has been a growing interest in the engineering education community to provide more engaging and active learning experiences for our students. A significant body of literature supports this shift and educators and explored and experimented with a wide variety of techniques to promote such deep learning. One approach that has been developed over the past 13 years is the inverted, or flipped, classroom. In some ways this approach borrows elements of a seminar class common in the arts and humanities, with the required readings being a critical piece of this mode of instruction, and the subsequent in-class discussion and debate where the learning takes hold. However, the inverted classroom approach goes beyond the seminar class and provides the instructor and student with a wide array of learning opportunities and tools.

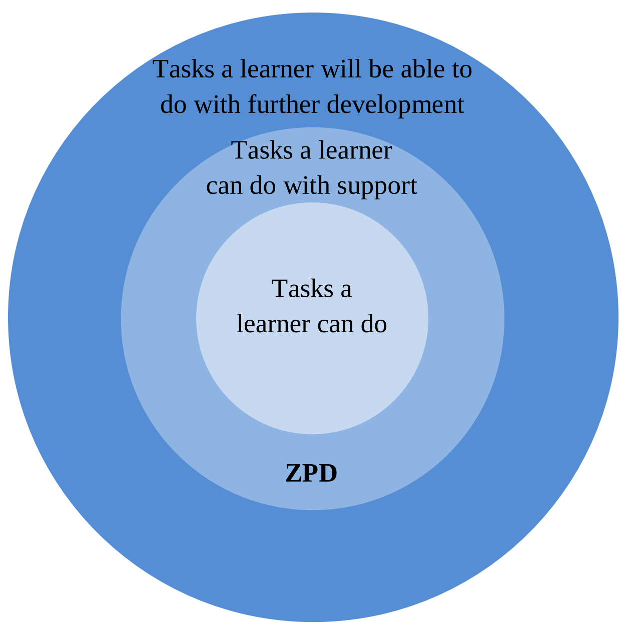
The general notion of an inverted classroom requires the students to gather the core knowledge needed before the class, so that they can then participate in meaningful activities during the lecture time. Typically, students are exposed to this fundamental knowledge through watching an online video prior to class. The instructor can then design the in-class time to be used for individual, group, or full-class learning experiences. If the students come well-prepared and the exercises are well-designed, then it is hoped that students will leave the face-to-face time with a deeper understanding of the core concepts, one which they have worked to develop through their own efforts with the support of their peers and the instructor.

The inverted classroom approach has a basis in three well-known principles of the science of learning: (a) Vygotsky's Zone of Proximal Development[1], (b) Bloom's Taxonomy of Learning[2], and (c) "How the Brain Learns" and the retention of core material[3]. Lev Vygotsky introduced the concept of a zone of proximal development (ZPD) to describe the intermediary state between the things a learner can do and the things a learner will be able to do with further development, as illustrated in Figure 1. He defined this to be:

"*The zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in the embryonic state.*"[1]

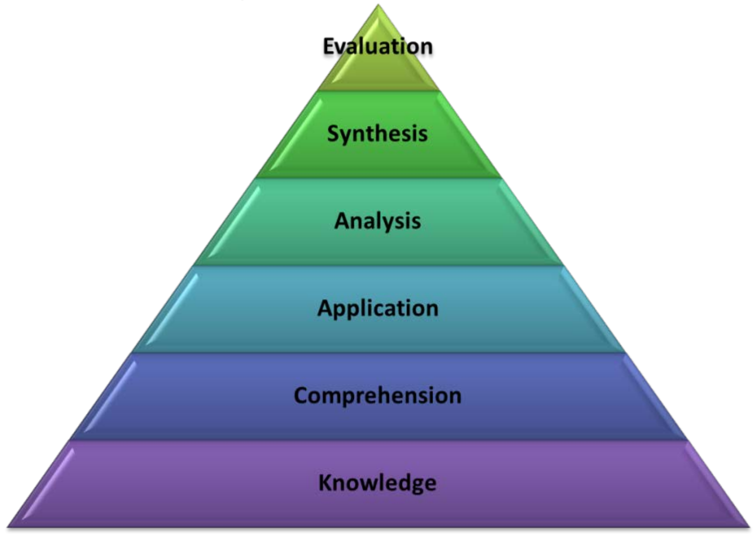
Through careful design, an instructor can create learning exercises which fall into the ZPD. The inverted classroom provides greater opportunity for such experiences given that the student can work through these exercises with the appropriate facilitation of their instructor.

Figure 1. Zone of Proximal Development



Similarly, in the 1950s a number of researchers worked to develop what is now known as Bloom's Taxonomy of Educational Objectives[2]. It is divided into three domains, Cognitive, Affective, and Psychomotor, with the Cognitive domain illustrated in Figure 2. The purpose of the taxonomy is to provide educators with a framework for learning objectives that they must set for their students. In a way, these are the basic levels through which a novice must progress through in order to master a subject. As noted by other inverted classroom practitioners, such as R. Talbert[4], and Bates and Galloway[5], through this teaching approach students can focus on the first one or two levels on their own through the pre-class material. This then allows students to have some additional support from their peers and their instructor as they move into the higher levels of Application and Analysis during the face-to-face time.

Figure 2. Bloom's Taxonomy of Educational Objectives – Cognitive Domain



Finally, it is known that the retention of new material requires that students "work" with new concepts and integrate these into their own existing knowledge system. In his book[3], David Sousa summarizes many years of research with a retention "pyramid" which illustrates that the rates of material retention 24 hours after instruction vary greatly depending on the mode of instruction. For example, people retain on average about 5% to 10% of material learned through purely verbal processing (lecturing or reading), while this increases to between 75% and 90% when instruction takes a more active form of "practice by doing" or "teach others/immediate use of learning".

Thus, it appears that the general tenets of the inverted classroom approach would support deeper learning through the fact that it enables:

1) Instructors to design activities and learning opportunities that ***provide the appropriate bridge*** between students' existing understanding and abilities with those that they should master as part of the course objectives,
2) Students to solicit support for and immediate feedback on their learning process during the in-class time through ***interaction*** with their peers and their instructor,
3) Students to engage in meaningful learning experiences through ***in-class activities and exercises***.

Further to this, the inverted classroom also addresses a number of Chickering and Gamson's Seven Principles for Good Practice in Undergraduate Education[6], including:

1) Encourages student-faculty contact,
2) Encourages cooperation amongst students,
3) Encourages active learning,
4) Gives prompt feedback, and
7) Respects diverse talents and ways of learning.

A more thorough discussion of the student-centered theoretical framework behind the inverted classroom can be found in a recent review paper by J. Bishop and M. Verleger[7].

Research Project Description

This paper reports on one of the research questions associated with a two-year study on the inverted classroom approach conducted at the Faculty of Applied Science and Engineering at the University of Toronto, which is a large research-intensive public university. The study compares the relative perception and performances of two cohorts, one taught using the traditional instructor-centred approach (2012 cohort), and one taught using the inverted classroom approach (2013 cohort). Both cohorts had about 330 students in total that were separated into two or three sections. Specifically, this paper summarizes the methods and results related to the question:

Does the inverted classroom teaching approach improve the students' perception of student/instructor interaction and the students' self-efficacy as compared to the traditional instructor-centered approach?

The study was based upon the instruction of the same core course on electric and magnetic fields that takes place within the second-year of standard electrical and computer engineering program. The two cohorts were taught by the same instructor and had the same first and second year pre-requisite courses. A summary of the two instructional approaches is presented in Table 1.

It should be noted that the traditional approach did incorporate some active exercises into the lectures, but the dominant approach was to use the in-class time for the transmission of new concepts and exposition of examples. On the other hand, due to the fact that the approach was used in a large lecture hall environment with approximately 100 students in each class, the inverted approach was not "purely" inverted, meaning that interspersed between the active exercises were mini-lectures in which the instructor summarized the key ideas of the previous exercises or went through the correct solution for that example. Overall, approximately one-half of the class time was used in this way. However, the overall focus of these classes was for the students to engage with the material and for the instructor to provide feedback based on the specific problems or concerns students were expressing. This meant the mini-lectures were more in response to students need rather than prepared lectures.

The remaining aspects of the two offerings of the course were nearly identical, including the textbook, the problem sets, the tutorial style involving group work exercises, and the number of primary assessments (quiz, midterm, and final exam).

Table 1. Description of the two Instructional Approaches

Cohort	Summary of Instructional Approach
Traditional Instructor-Centered Approach (2012)	• Lecturing style included the use of a tablet computer instead of the chalkboard, with lecture outlines posted for students prior to class. • In-class questions posed to the class through the use of a classroom response system (iclickers) (approximately 1 per class). • No complete annotated notes or videos of the lectures were provided. • Lectures followed general structure of: (a) concept motivation/introduction/definitions/derivations, (b) example problem(s), and occasionally (d) discussion of engineering applications and/or (e) experimental demonstrations.
Inverted Classroom Approach (2013)	• Students were asked to watch videos prior to class (ranged between 16 to 37 minutes, with an average length of 24 minutes). • Videos typically covered the (a) concept motivation/introduction/definitions/derivations component, and usually one (b) example problem. • Each video contained "pop-up" quizzes (usually 2 per video and occurred every 10 to 15 minutes). • A 7% *Course Participation* grade provided incentive to watch the videos and complete the quizzes prior to the associated class. • The in-class time included a variety of active exercises including classroom response questions with peer instruction opportunities, and individual and group problem solving experiences. These were based on in-class outlines provided to students before the class. • During the exercises the instructor circulated through the traditional lecture hall of approximately 100 students. • After a period of activity the instructor reviewed or summarized the solutions to problems with the entire class, through the use of a tablet instead of the chalkboard. • An edited video of these summary discussions were provided to students after each class. • An online discussion forum was used and supported throughout the course which enabled students to post and answer their questions[8].

Background

The idea of the inverted classroom approach was first presented by a group of economics professors in 2000[9]. While this paper primarily focused on describing the method, the student and faculty perceptions of this approach were quite positive. The students which were the focus of another inverted classroom study, also reacted quite positively to this technique[10]. The essential results from that paper were that: (a) most students (78%) appreciated the ability to view the lectures in their own time and pace, (b) the rating of the usefulness of the face-to-face time (lecture) was higher for the inverted approach relative to the traditional approach, and (c) it was noted that the majority of students thought that the course did not require more work than a traditional course (76%). However, in both of these studies students had problems with the technical delivery of the videos and the usability of the videos (e.g., easy fast-forwarding or rewinding) due to the immaturity of the required technology.

As the lecture-capture technology has improved dramatically over the past 10 years, it has become even easier for the average computer user to prepare the short lecture videos needed for this teaching approach. As this technology has become more available, there have been a greater number of instructors at institutions throughout the world which are moving to this model of teaching. As a result, there has been a growing body of literature relating to the inverted classroom, however most papers continue to describe the particulars of the approach and the students' perceptions of the method. There is still a lack of rigorous study of the inverted classroom, with only a couple of papers presenting statistical analysis of learning gains.

One such paper was presented at the 2010 American Society for Engineering Education Conference and Exposition[11]. This paper presents a combination of positive qualitative and quantitative data. The quantitative results indicate that the inverted model has a greater positive effect on the learning of the basic concepts than the traditional model. Specifically, they found a larger increase between the pre- and post-test scores on a concept inventory quiz for the students who were exposed to the inverted classroom versus those that were taught using a traditional method. However, when they analysed the individual learning gains they did not find a statistically significant difference. One reason for this might be due to their small sample size (Inverted: n = 43, Traditional: n = 11).

Recently a more thorough review of the research related to the inverted classroom has been published[7]. The essential conclusions of this review was that overall students responded quite positively to the new teaching approach, but there was a lack of research that focused on measuring student learning outcomes. Over the past year there have been some papers that have specifically addressed these learning outcomes[5,12,13,14,15]. McClelland found that a group of students taught using the inverted approach (n = 146) performed slightly, but statistically significantly worse on the same final exam that was given to the traditionally taught cohort (n = 149) in the previous course offering (Avg. Inv. = 80.2%, Avg. Trd. = 83.7%). Similar results were observed for quizzes that were given throughout the term[12]. On the other hand, some other authors found that that the inverted approach improved conceptual understanding[5,15], but Choi found that it did not improve the overall performance in the course[15]. The other papers have reported no significant difference between the traditional and inverted cohorts on common exams[13,14].

In all cases, the importance of student engagement with the new learning approach for successful outcomes has been highlighted. It was observed by Love, et. al., that as students progressed through the term and seemingly adapted to the inverted classroom method the improvements between term test scores, relative to the same gains made by a traditional cohort, were significantly better[14].

Research Methods

At the outset of this project various research study designs were considered, and it was decided to use a mixed-methods approach with the control and treatment groups being cohorts of different years (control – 2012, and treatment – 2013). The reason for this was that it was hypothesized that the two cohorts would have very similar characteristics and academic abilities given that the design was focused around a core course in the second year of a fixed program (at this institution within this engineering department the courses over the first two years are fixed.) Over the two years a series of data were collected using the same method or instrument. These are summarized in Table 2.

Table 2. Summary of Study Data

Data Component	**Method of Collection**	**Counts**	
		2012 *Traditional*	**2013** *Inverted*
Lecture attendance	Through sign-in sheets, attendance was recorded during each lecture (except when exams took place) starting from the second week.	29 lectures (304 total registered students)	28 lectures (334 total registered students)
End-of-term student survey	The paper version of the survey was distributed by the research associate to students during the last day of classes. An online version was also made available (approximately 10% of the responses were completed online.)	179 (59% response)	180 (54% response)
Learning style assessment	The assessment tool was the Index of Learning Styles (ILS) Questionnaire[16]. In the second month of the term, students were asked to complete this online questionnaire and then enter their results as part of an online survey for the course.	266	285
Concept inventory (pre-test)	The 31 question multiple choice pre-test was completed in the Friday of the first week of classes. The students were given 50 minutes to complete the test, which was equivalent to the verified Brief Electricity and Magnetism Assessment (BEMA) test[17] developed by a group of physics educators. Students were given a 1.5% grade as part of their course mark for just taking the test.	306	332
Concept inventory (post-test)	The 28 question multiple choice post-test was completed in the Friday of the final week of classes. The students were given 50 minutes to complete the test, which included 14 questions from the BEMA pre-test and 14 questions from the Electric and Magnetic Fields concept inventory created by Branislav Notaros[18]. Students were given a 1.5% bonus mark for the course just for taking the test.	289	305

Data Component	Method of Collection	Counts	
		2012 *Traditional*	**2013** *Inverted*
Concept inventory (gain)	Derived from the repeated 14 questions in both pre-test and post-test assessment	279	301
Prior academic performance	For those students that signed the Informed Consent agreement, the Faculty's Registrar provided their academic performance for their first 15 courses (i.e., their first 3 terms), since the course for this study is taken in their fourth term.	154	204
In-class quizzes (measuring the students Analytic Problem-Solving Capabilities)	Four problem-solving quizzes were administered to the students in class throughout the term. These were exactly the same for both cohorts, and were written at the same points of the term for each cohort.	335	352
Course grades	In both years the course had three major summative assessments, a term test (8%), a midterm (20%), and a final exam (40%). The remaining grades consisted of marks for tutorial group work, computer MATLAB labs, small quizzes, and course participation. The major assessments were of similar style, covered the same material, but had different questions since the previous year's questions were available to the students.	299	329
Long-term retention	In the following term (fall of third year) students were invited to write a 50 minute quiz, which tested their retention of the core concepts from the course on Electric and Magnetic Fields.	69	51
Video watching	For the inverted cohort, the video viewing analytics for each student was recorded and analyzed at the end of the term. From this it could be determined which students watched the videos prior to the appropriate class and how much of the video that student watched.	N.A.	338
Focus groups	At the end of each term, a few focus group sessions were held. Each session lasted approximately one hour long.	3 sessions, with a total attendance of 8 students	4 sessions, with a total attendance of 14

Results

The following set of results summarize the data within the study that relate to cohort comparison, perception of student/faculty interaction, student self-efficacy, and how the perception of student/faculty interaction and student self-efficacy contributed to student learning. A companion paper[19] focuses more on the students' reaction to the inverted classroom approach, how they participated with the approach, a preliminary comparison of their learning, and lessons learned by the course instructor.

Part 1: Cohort Comparison

The two student cohorts were compared in three areas: (1) learning style; (2) prior academic performance; and (3) Concept Inventory pre-assessment scores. No statistically significant difference was found between the two student cohorts in these three areas (see Table 3). This suggests that the two student cohorts were comparable and supports the notion that the data collected from them were good for the purposes of this study.

Table 3. Descriptive Statistics of Indicators for Cohort Comparisons

	Traditional Cohort		Inverted Cohort	
	n	% or Mean (SD)	n	% or Mean (SD)
Learning Style - Active/Reflective: Reflective	266	53%	285	58%
Learning Style - Sensing/Intuitive: Sensing	266	61%	285	63%
Learning Style - Visual/Verbal: Visual	266	79%	285	81%
Learning Style - Sequential/Global: Sequential	266	60%	285	62%
Prior academic performance (total score: 100)	154	73.2 (9.35)	204	73.7 (9.33)
Concept Inventory scores: pre-test (total score: 31)	306	14.2 (4.75)	332	14.3 (4.73)

Part 2: Perception of Student/Faculty Interaction

Two sets of student/faculty interaction questions were asked: (1) frequency questions on a 6-point scale ranging from "never" (1) to "more than once a week" (6); and (2) satisfaction questions on a 5-point scale ranging from "very dissatisfied" (1) to "very satisfied" (5). A 4-point scale question was asked to indicate students' perceptions of the level of adequacy of their personal interaction with the instructor, ranging from "not at all adequate" (1) to "very adequate" (4).

Table 4 shows that when the new teaching approach was taken in 2013, students had significantly higher frequency of interactions with the instructor during and immediately after class and were more satisfied with the interactions with the instructor during class than students did in 2012.

Table 5 shows that when the inverted classroom approach was employed, those who *never* had interactions with the instructor *during class* dropped to 24.7% from 54%, the percentage of students who had no interactions with the instructor when the traditional approach was used. Among the inverted cohort, 25.5% reported that they had interactions with the instructor during class "about once a week," "two to three times a month," or "about once a month," as compared with 13.6% among the traditional cohort.

Table 6 shows that when the inverted classroom approach was adopted, 69.4% of the students expressed satisfaction with their interactions with the instructor during class, as compared with 50.9% when the traditional approach was used.

Table 4. Comparisons of Students/Instructor Interactions

	Traditional Cohort			Inverted Cohort			Mean Diff.	Sig.
	n	Mean	SD	n	Mean	SD		
Frequency of student-instructor interactions								
During class	176	1.86	1.30	174	2.58	1.47	0.72	***
Immediately after class	175	1.76	1.05	177	2.06	1.22	0.30	*
During the instructor's office hours	175	1.62	0.98	174	1.24	.53	-0.38	***
Outside the class (e.g., hallway conversation)	175	1.54	0.96	176	1.58	.93	0.04	
Satisfaction with student-instructor interactions								
During class	165	3.58	0.83	173	3.91	.92	0.33	**
Immediately after class	166	3.59	0.86	172	3.68	.92	0.09	
During the instructor's office hours	167	3.57	0.86	163	3.41	.84	-0.16	
Outside the class (e.g., hallway conversation)	165	3.50	0.82	166	3.50	.87	0.00	
Perceived adequacy of student-instructor interactions								
Overall, the level of my personal interaction with the instructor for ECE221 this term was	163	2.38	1.01	171	2.56	.96	0.18	
$* p \leq .05$; $** p \leq .01$; $*** p \leq .001$								

Table 5. Frequency of Students' Interactions with the Instructor

Question: Think of your personal interaction with the instructor for ECE221 this term, indicate how often you interacted with the instructor in the following situations.	Never	A few times during the term	About once a month	Two to three times a month	About once a week	More than once a week
Traditional cohort (2012)						
During class	**54.0%**	28.4%	6.3%	4.0%	3.4%	4.0%
Immediately after class	52.0%	33.7%	4.6%	5.7%	4.0%	0.0%
During the instructor's office hours	**60.6%**	27.4%	4.6%	5.1%	1.7%	0.6%
Outside the class (e.g., hallway conversation)	66.3%	22.9%	5.1%	2.9%	2.3%	0.6%
Inverted cohort (2013)						
During class	**24.7%**	39.7%	8.0%	12.6%	10.3%	4.6%
Immediately after class	41.8%	31.6%	11.3%	10.2%	4.0%	1.1%
During the instructor's office hours	**81.6%**	13.2%	5.2%	0.0%	0.0%	0.0%
Outside the class (e.g., hallway conversation)	61.4%	27.3%	6.3%	2.8%	1.7%	0.6%

Table 6. Students' Satisfaction with the Interactions with the Instructor

Question: Thinking of your personal interaction with the instructor for this course, indicate how satisfied you were with the level of interaction in the following situations:	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied
Traditional cohort (2012)			
During class	6.7%	42.4%	**50.9%**
Immediately after class	5.4%	45.8%	48.8%
During the instructor's office hours	6.0%	47.9%	46.1%
Outside the class (e.g., hallway conversation)	4.2%	56.4%	39.4%
Inverted cohort (2013)			
During class	4.5%	25.8%	**69.7%**
Immediately after class	6.2%	37.3%	56.5%
During the instructor's office hours	6.5%	55.4%	38.1%
Outside the class (e.g., hallway conversation)	5.3%	49.1%	45.6%

The findings about student/instructor interactions are also supported by some of the qualitative data. When asked "In terms of supporting your learning of the course material, what was the most useful aspect of the classroom experience (i.e., the lectures)?" in the student survey, some student comments from the inverted cohort included:

> *Instructor interaction*
>
> *Questions and Answers in class*
>
> *Quality of examples; interactive nature of the class*
>
> *Being able to ask questions and get my answers on the spot. This helps tie the answer more closely to all the details surrounding the question*
>
> *It was more interactive, and focused more on reviewing material that was already taught from the videos.*
>
> *The interaction the instructor had with students, i.e., not always writing on a chalkboard and showing experiments.*

Additionally, the relevant student comments from the 2013 focus group sessions were:

> *He walks around and when he's asking these little questions he walks around the room, looking for people who have questions. If you have a question he'll come over and discuss it with you one on one or with your little group and it connects us with the professor so we feel more comfortable asking questions and that's good.*
>
> *Last term, I didn't do any interaction. This time I did, actually. Once per week. Actually I tried to raise my hand to try to answer some question.* (a student who had taken the course last year and retook the course this year)

Part 3: Self-efficacy

A total of 30 self-efficacy questions on a 7-point Likert scale were asked to students to investigate their level of confidence in various aspects of the course materials and studying engineering. Those related to Engineering Self-Efficacy were taken directly from the Longitudinal Assessment of Engineering Self-Efficacy instrument[20]. Through factor analysis using polychoric correlation, three factors were derived. Those questions and related factors are reported in Table 7.

Table 7. Cronbach's Alpha and Loaded Factors of Measuring Self-Efficacy

Factors	**Cronbach's Alpha**	
	Traditional Cohort	*Inverted Cohort*
Self-efficacy related to explaining course concepts to others (13 questions)	0.96	0.96
Self-efficacy related to studying engineering (11 questions)	0.91	0.90
Self-efficacy related to learning the material in this course (6 questions)	0.90	0.87

Table 8 shows that there was no significant difference between the two cohorts regarding the three self-efficacy factors.

Table 8. Comparisons of Self-Efficacy Variables

Factors	**Traditional Cohort**			**Inverted Cohort**			Mean	
	n	Mean	SD	n	Mean	SD	Diff.	Sig.
Self-efficacy related to explaining concepts to others	174	4.54	1.28	173	4.43	1.28	-0.11	
Self-efficacy related to studying engineering	170	5.11	1.12	169	5.14	1.04	0.03	
Self-efficacy related to learning the material in this course	176	5.18	1.12	176	5.20	0.95	0.02	

Part 4: Contributions of Student/Faculty Interactions and Self-Efficacy to Student Learning

The traditional and inverted cohorts were compared in terms of four learning outcome variables, which were:

1) *Short-term Conceptual Gain Score*: This was a comparison of the common 14 questions on the pre/post concept inventory quizzes done at the beginning and the end of the terms. The standard conceptual gain formula, as proposed by Hake, has been used[21].
   It should be noted that a comparison of the gain scores might not be appropriate given the different conditions under which the post quiz was written for the two cohorts. The traditional cohort (2012) wrote the post quiz 4 days before the final exam for the course, whereas the inverted cohort wrote this quiz 11 days prior to the final exam. While the students were told to "not prepare or study" for the post quiz, it is likely that many students in the traditional cohort had already started to review the course material in preparation for the final exam.

2) *Analytic Problem-Solving Capabilities*: This measure was derived from the average of the four in-class quizzes that were completed by both cohorts throughout the term. The quizzes were identical for each cohort. These questions focused on solving problems related to the course material as opposed to the conceptual-based questions used in the concept inventories.
3) *Course Academic Performance*: This is the overall final course mark for each student. It should be noted that while the mark breakdown for the two cohorts was very similar, as was the types and coverage of major assessments, these tests, midterms, and final exams had different questions.
4) *Long-term Conceptual Understanding*: This is the mark on the concept inventory quiz given to participating students in the beginning of the following fall term of third year.

Table 9 shows that the scores of Analytical Problem-Solving Capabilities among the inverted cohort were significantly higher than those of the traditional cohort, with the mean difference of 1.48, $SE = .23$, $t = 6.49$ ($df = 245$), $p < .001$. In addition, the Course Academic Performance of the inverted cohort was better than that of the traditional cohort, with the mean difference of 3.05, $SE = 1.07$, $t = 2.84$ ($df = 626$), $p < .01$; Nevertheless, this result should be viewed with caution as the questions in the test, midterm, and final exam were different in the two years.

Table 9. Descriptive Statistics of the Indicators of Teaching Effectiveness and Mean Differences

	2012 data			2013 data			Sig. in mean diff.
	n	range	Mean (SD)	n	range	Mean (SD)	
Gains in Short-term Concept Understanding	279	-250 to 100	17.9 (48.73)	301	-167 to 100	13.4 (41.61)	
Analytical Problem-Solving Capabilities	130	1.25 to 8.75	4.64 (1.79)	117	1.69 to 9.75	6.12 (1.79)	***
Course Academic Performance	299	29.9 to 100	70.36 (13.73)	329	38.7 to 100	73.41 (13.12)	**
Long-term Concept Understanding	69	3 to 16	9.61 (2.89)	51	2 to 19	9.55 (3.84)	

** $p \leq .01$; *** $p \leq .001$

Correlation analysis was also performed with the following three groups of variables:

1) Two learning outcome variables with significant difference between the traditional and inverted cohorts (i.e., Analytical Problem-Solving Capabilities (APSC) and Course Academic Performance (CAP));
2) Four interaction variables with significant difference between the traditional and inverted cohorts (i.e., frequency of interactions with instructor during class, immediately after class and during the office hours; and satisfaction with interactions with instructor during class);
3) Three self-efficacy variables (i.e., self-efficacy factors 1, 2 and 3), along with one variable that represents students' characteristics prior to taking the course – Prior Academic Performance (PAP).

Table 10 shows that all self-efficacy variables are significantly correlated with the two learning outcome variables for both student cohorts while only frequency of interactions with instructor during class was significantly correlated with APSC and CAP for the traditional cohort and significantly correlated with CAP alone for the inverted cohort. When controlling for the differences in learning styles and Prior Academic Performance, the interaction variable was not found significant to either of the learning outcome variables.

Table 10. Correlation Matrix of Learning Outcome Variables and Prior Academic Performance, Interaction Variables and Self-Efficacy Variables

2012 data	APSC	CAP	PAP	Inter1	Inter2	Inter3	Sat	SE1	SE2	SE3
Outcome1: Analytical Problem-Solving Capabilities (APSC)	1	.768**	**.599****	**.247***	.186	.014	.098	**.404****	**.479****	**.476****
Outcome2: Course Academic Performance (CAP)		1	**.775****	**.173***	.134	.070	.106	**.268****	**.457****	**.343****
Prior academic performance (PAP)			1	.127	.141	-.081	-.009	.130	.363**	.180*
Interactions with instructor1: during Class				1	.719**	.464**	.389**	.301**	.172*	.182*
Interactions with instructor2: Immediately after class					1	.647**	.262**	.314**	.151	.211**
Interactions with instructor3: during the instructor's office hours						1	.180*	.199**	.006	.105
Satisfaction with interactions with instructor during class							1	.274**	.203*	.145
Self-efficacy: Factor1								1	.589**	.693**
Self-efficacy: Factor2									1	.617**
Self-efficacy: Factor3										1

2013 data	APSC	CAP	PAP	Inter1	Inter2	Inter3	Sat	SE1	SE2	SE3
Outcome1: Analytical Problem-Solving Capabilities (APSC)	1	.670**	**.537****	0.157	.076	.067	-.030	**.383****	**.392****	**.463****
Outcome2: Course Academic Performance (CAP)		1	**.793****	**.168***	.057	-.146	.068	**.462****	**.528****	**.414****
Prior academic performance (PAP)			1	.124	.010	-.173*	-.012	.353**	.567**	.357**
Interactions with instructor1: during Class				1	.591**	0.119	.380**	.192*	.163*	.232**
Interactions with instructor2: Immediately after class					1	.367**	.325**	.199**	.034	.158*
Interactions with instructor3: during the instructor's office hours						1	-0.011	-0.030	-.217**	-.049
Satisfaction with interactions with instructor during class							1	0.144	.158*	.219**
Self-efficacy: Factor1								1	.532**	.606**
Self-efficacy: Factor2									1	.669**
Self-efficacy: Factor3										1

Discussions

To answer the primary research question for this paper:

Does the inverted classroom teaching approach improve the students' perception of student/instructor interaction and the students' self-efficacy as compared to the traditional instructor-centered approach?

Here is a summary of our findings from the analysis of the data:

- When the inverted classroom approach was adopted, the frequency of the interactions between the students and the instructor considerably increased during the class and immediately after the class.
- When the inverted classroom approach was adopted, the frequency of the student-faculty interactions decreased during the instructor's office hours. This may be a result of the increased opportunities to interact with the instructor during and immediately after the class. In addition, the use of an online question and answer discussion forum enabled students to have their questions answered by their peers and the course teaching staff[8].
- A higher proportion of the students who took the course delivered in the inverted classroom approach expressed their satisfaction with their interactions with the instructor during the class than those who took the course delivered in a more traditional way.
- No significant difference was found in students' self-efficacy in explaining certain concepts to others, in studying engineering, and in learning in the course. However, a lower proportion of the students who studied in the inverted classroom approach reported that they were confident of explaining the conceptual part of how magnetic fields relate to their sources and materials. This may be due to the fact that some additional emphasis was placed on problem-solving when the inverted classroom approach was used so some students may not have developed as strong a conceptual understanding.
- In terms of learning outcomes, students who learned in the inverted classroom environment did considerably better in their analytical problem-solving capabilities than those who studied in a more "traditional" learning environment. However, the inverted classroom approach did not produce evident improvement in students' conceptual understanding.
- The increased frequency in students' interactions with the instructor did not contribute much to students' analytical problem-solving capabilities and their final grades.
- To both student cohorts, self-efficacy scores were moderately correlated with the both analytical problem-solving capabilities and final grades, with correlation coefficients ranging from .27 to .48 for the 2012 cohort and from .38 to .53 for the 2013 cohort; prior academic performance was highly correlated with both of the learning outcomes, with correlation coefficients being .60 and .78 for the 2012 cohort and .54 and .79 for the 2013 cohort.

Conclusions

This paper contributes to existing literature as well as current teaching and learning practice using the inverted classroom approach in the following ways.

First, the paper aimed to examine the effects of an innovative instructional approach – the inverted classroom approach – on students' learning experiences and outcomes. Essentially, it is a study on the "within-college effects" on students' subject matter learning according to Pascarella and Terenzini's framework[22]. Our research design spanned over two years and related to two student cohorts exposed to the "traditional" approach and the inverted classroom approach respectively. The research design allowed us to compare various aspects of student learning experiences and outcomes. In terms of learning outcomes, we assessed both students' concept understanding and their analytical problem-solving capabilities in addition to their grades. Given the lack of research focusing on measuring student learning outcomes in the existing literature on the inverted classroom approach, our paper has enriched the understanding of the effects of the approach on student learning. Our findings show that the inverted classroom approach may have greater impact on certain types of learning outcomes, such as problem-solving competencies, than others, such as conceptual understanding. However, the confounding factors which were present within this study may have resulted in a flawed measurement of the gain conceptual understanding.

Second, our analysis has confirmed that the inverted classroom approach will enhance students' interactions with the instructor, a finding concurring to other studies[9,10]. The strength results from a greater number of interactive learning opportunities that were incorporated into the inverted classroom learning environment. Although the effects of the greater student/faculty interaction were not found significant to learning outcomes while controlling for other factors, the impact of the interactions may have been mediated by other factors, possibly students' learning styles. Further investigations are needed in that regard. In addition, our analysis has also confirmed that students' self-efficacy is positively correlated with their learning outcomes.

Third, our research project was a product of the instructor's first attempt to use the inverted classroom approach. Our data showed that some students were not satisfied with the new learning environment simply because they were not used to the new ways of learning that resulted from the instructor's use of the approach. Only 56.2% of the students watched more than half of the lesson videos before the classes. The lack of students' commitment to the approach became a limitation in our study that aimed to detect the net effect of the inverted classroom approach. Another factor was that despite the fact that the instructor was fully committed to using the approach, in teaching practice he had to accommodate the needs of the students who were exposed to the new learning environment. This made the actual classroom not completed "inverted." However, our analysis has confirmed that the inverted classroom approach does improve students' learning in certain ways, particularly with their problem-solving capabilities. Through further refinement and careful design of the entire learning experience it is likely the effectiveness of this new teaching method will continue to improve.

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Appendix

Questions Within the Self-Efficacy Factors

Factors	Question items
Self-Efficacy Factor 1 Self-efficacy in explaining course concepts to others 13 questions Cronbach's alpha = .96 (2012 data) and .96 (2013 data)	I have a good understanding of the basic concepts of electric and magnetic fields. I can verify that my mathematical answer is correct for this type of problem by using my understanding of the essential concepts of how electric and magnetic fields behave. I can clearly explain the essential concepts of how electric and magnetic fields behave to a grade 9 high-school student. I can clearly explain the essential concepts of how electric and magnetic fields behave to another second-year ECE student. I can clearly explain the essential concepts of how electric and magnetic fields behave to an ECE professor. I can clearly explain the basic relationship between **electric** fields and their sources (charges) to another second-year ECE student. I can clearly explain how electric fields interact with materials, such as conductors and insulators, to another second-year ECE student. I can clearly explain how **electric** fields interact with materials, such as conductors and insulators, to another second-year ECE student. I can clearly explain the basic relationship between **magnetic** fields and their sources (currents) to another second-year ECE student. I can clearly explain how **magnetic** fields interact with materials, such as iron, to another second-year ECE student. I can clearly explain how **magnetic** fields are applied to solve engineering problems (i.e., through inductance, energy storage, motors/generators, etc.) to another second-year ECE student. I can clearly explain the basic operation of **time-varying electromagnetic fields** through Faraday's and Lenz's laws to another second-year ECE student. I can clearly explain how **time-varying electromagnetic** fields can be applied (i.e., through transformers, etc.) to another second-year ECE student.

Self-Efficacy Factor 2 Self-efficacy in studying engineering 11 questions Cronbach's alpha = .91 (2012 data) and .90 (2013 data)	I will succeed (earn an A or B) in ECE221H1S: Electricity and Magnetism. I can succeed in an engineering curriculum. I can succeed in an engineering curriculum while not having to give up participation in my outside interests (e.g. extracurricular activities, family, sports). I will succeed (earn an A or B) in my physics courses. I will succeed (earn an A or B) in my math courses. I will succeed (earn an A or B) in my engineering courses. I can complete the math requirements for my engineering major. I can excel in my engineering major during the current academic year. I can complete any engineering degree at this institution. I can complete the physics requirements for my engineering major. I can persist in engineering during the current academic year.
Self-Efficacy Factor 3 Self-efficacy of learning the material in this course 6 questions Cronbach's alpha = .90 (2012 data) and .87 (2013 data)	I can draw or visualize a three dimensional picture based on the word description of the problem. I can determine the appropriate differential length, surface, or volume element (*dl*, *ds*, or *dv*) needed to solve the problem. I can evaluate the required line, surface, or volume integral needed to solve the problem. I can do the vector mathematics required for these types of problems (e.g., addition, subtraction, working with unit vectors, and coordinate system conversions). I can create a clear plan to solve this type of problem before I write down or use any formulas or equations. I can use the required vector calculus operators (i.e., curl, gradient, and divergence) in the three main coordinate systems to solve the problem.