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The Effects of the Inverted Classroom Approach: Student Behaviours, Perceptions and Learning Outcomes – Appendix

Micah Stickel, Qin Liu
University of Toronto

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1 Yonge Street, Suite 2402
Toronto, ON Canada, M5E 1E5

Phone: (416) 212-3893
Fax: (416) 212-3899
Web: www.heqco.ca
E-mail: info@heqco.ca

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Appendix A: Data Collection Methods

Table A-1: Summary of Data Components and Associated Data Collection Methods

	Data Components	Methods of Data Collection
1	*Prior academic performance*	For those students who had signed the informed consent agreement to act as participants in this research project, the Faculty's registrar office provided their average grades for their first 15 courses, i.e., courses students had taken in their first three terms before the course in which this study was conducted.
2	*Learning style assessment*	The assessment tool was the Index of Learning Styles (ILS) Questionnaire (Felder & Soloman, n.d.; Lizinger, Lee, Wise & Felder, 2007). The tool is available online for free. In the second month of the term, students were asked to complete the questionnaire and then enter their results as part of an online survey for the course.
3	*Lecture attendance*	Students attending the lecture were asked to sign an attendance sheet beginning from the second week of the course. Attendance was recorded except when other course tests and midterms took place.
4	*Lesson video viewing*	For the 2013 cohort only, the video viewing analytics for each student were recorded and analyzed at the end of the term.
5	*Concept inventory:* *Pre-test score*	The inventory consisted of 31 multiple-choice questions. Students were asked to complete the pre-test during the first week of the course. The test took 50 minutes to complete and was exactly the same as the verified Brief Electricity and Magnetism Assessment (BEMA) test developed by a group of physics educators (Ding, Chabay, Sherwood & Beichner, 2006). Students had 1.5% added to their course mark simply for taking the test.
6	*Concept inventory:* *Post-test score*	The inventory consisted of 28 multiple-choice questions. Students were asked to complete the post-test during the final week of the course. The test took 50 minutes to complete and included 14 questions from the BEMA pre-test and 14 questions from the Electric and Magnetic Fields concept inventory created by Branislav Notaros (Notaros, 2002). Students had 1.5% added to their course mark simply for taking the test.
	Concept inventory: Gain score	Derived from the 14 questions repeated in both the pre-test and post-test assessments. The gain calculation was based on Hake's formula (Hake, 1998): $$Gain = \frac{Post\ Test\ Score - Pre\ Test\ Score}{100 - Pre\ Test\ Score} \times 100\%$$ This provides a measure of student improvement on the common 14 pre/post-test items as a percentage relative to the maximum possible improvement.

	Data Components	Methods of Data Collection
7	*In-class analytic problem-solving quizzes*	Four problem-solving quizzes were administered to the students in class throughout the term. These were exactly the same for both cohorts. The students wrote the quizzes at the same points of the term without knowing before the classes. These quizzes were kept secure and confidential, as no copies or solutions were ever posted for students. So the inverted cohort did not have any prior exposure to the quizzes. The four in-class analytic problem-solving quizzes were equally spaced throughout the term and each quiz covered a topic that had already been covered in lecture or class two weeks prior to the quiz and in tutorials the week before the quiz. These quizzes targeted the students' ability to solve problems analytically by combining the requisite conceptual understanding and the required mathematics knowledge and skills. Among the 2012 cohort, 215, 205, 204 and 222 students took the four quizzes, respectively. Among the 2013 cohort, 242, 207, 227 and 168 students took the four quizzes, respectively. Students were also asked to rate their confidence in answering each part of the problems on a scale of 1 ("Basically Guessed") to 5 ("Sure") to 10 ("Very Sure").
8	*End-of-term student survey*	The survey consisted of three sections (see Appendix E for the 2013 questionnaire): *Students' Preferences* (14 questions in 2012, 31 questions in 2013) *Students' Personal Interactions, Engagement and Perceptions* (11 questions) *Self-Efficacy* (31 questions) The 2013 survey added some questions that were specifically related to the inverted classroom approach. Questions were written by the research team, with the exception of those questions that measured self-efficacy in studying engineering, which were taken directly from the validated Longitudinal Assessment of Engineering Self-Efficacy instrument (Marra, Rodgers, Shen & Bogue, 2009). The psychometric properties of all questions were examined in the data analysis process. The paper version of the survey was distributed by the research assistant to students during the last day of classes. An online version was also made available at the same time. Approximately 10% of the responses were completed online. The response rates were 56% (167 students) and 54% (177 students), respectively, for the 2012 and 2013 cohorts.

	Data Components	Methods of Data Collection
9	*Faculty course evaluations*	The faculty course evaluation questionnaire was the faculty's official procedure for course evaluation and was typically completed by students during the last week of the course. The data were obtained from the faculty registrar's office. The response rates were 36% (113 out of 310 enrolled students) and 39% (133 out of 338 enrolled students), respectively, for the 2012 and 2013 cohorts.
10	*Focus groups*	At the end of each term, focus group sessions were held. Each session lasted approximately one hour. The student participants were asked about their learning experiences and their perceptions of the instructional approach. For the 2012 cohort, 3 sessions were run, with a total attendance of 8 students. For the 2013 cohort, 4 sessions were, with a total attendance of 14 students
11	*Course academic performance (final course grade)*	In both years the course had three major 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 similar in style and covered the same materials but had different questions because the previous year's questions were available to the students. The course instructor intended tests in both years to be of similar difficulty, though test properties were not compared statistically. In 2012, a total of 299 students completed the course; in 2013, a total of 329 students completed the course.
12	*Long-term concept retention test*	In the term following the course (the fall semester of the third year), the students were invited to write a 50-minute quiz that tested their retention of core concepts from the course on electric and magnetic fields. While the questions were similar to those on the post-test, they were not identical. In the 2012 cohort, 23% (69 students) took the quiz; in the 2013 cohort, 16% (51 students) took the quiz.

Appendix B: Index of Learning Styles (ILS)

Learning Style Distributions

The Felder-Silverman Index of Learning Styles uses scores from ±1 to ±11 to map a person's learning preference within four domains. From this score a person's preference for each style can be categorized as mild, moderate or strong, as shown in the two figures below. It can be observed from these figures that the detailed distributions between the two cohorts were very similar. Due to this similarity and to simplify the analysis, a simple learning style classification was used in the regression analysis. This simple classification combined the mild, moderate and strong categories into one. For example, the simple distribution for 2012 has a 59%/41% Sequential/Global split, while for 2013 this is 62%/38%.

Figure B-1: Detailed Learning Style Distribution – Traditional (2012)

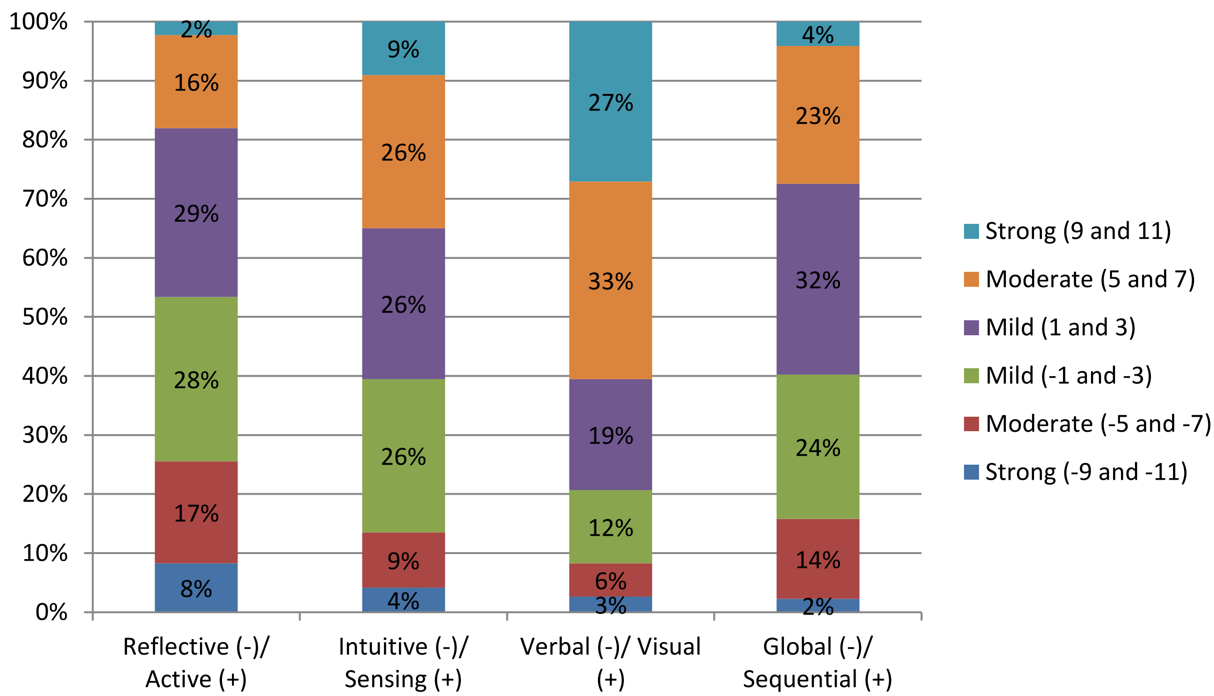
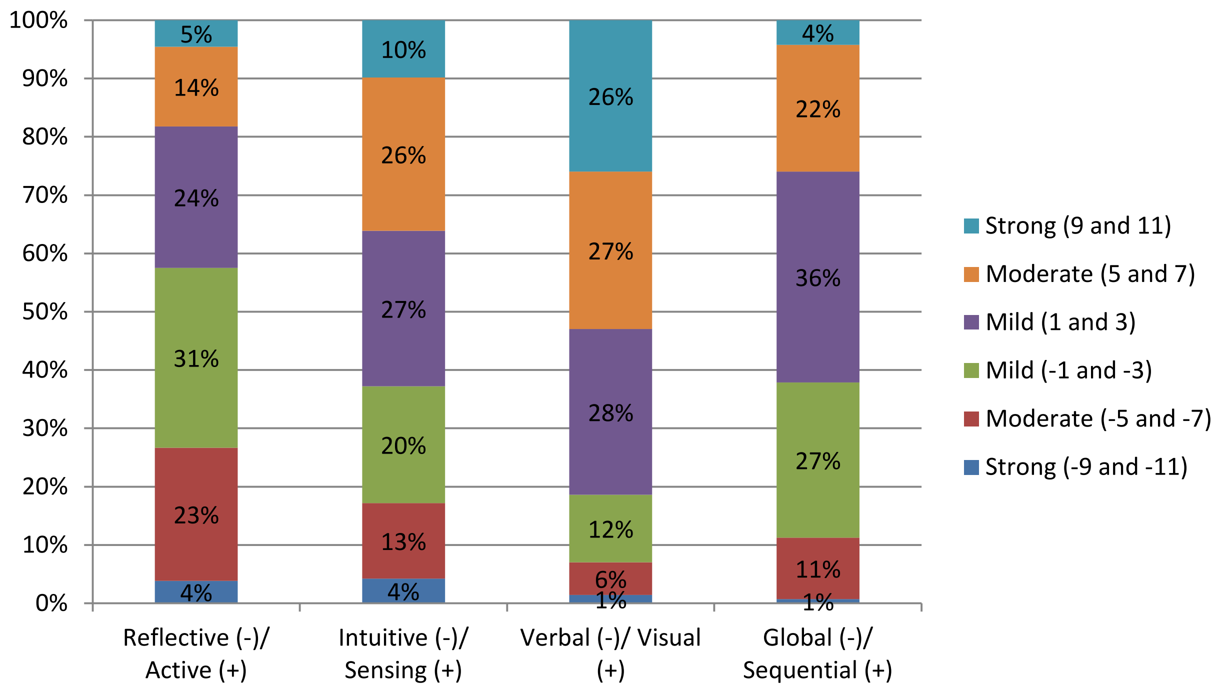


Figure B-2: Detailed Learning Style Distribution – Inverted (2013)



An Abbreviated Summary of the Index of Learning Styles[1]

This index ranks a person's preference in four essential modes of learning:

Active or Reflective Modality

Active learners tend to retain and understand information best by doing something with it, such as explaining it to others. They often like to work in groups.
Reflective learners tend to learn better by thinking things through and often prefer to work alone.

Sensing or Intuitive Modality

Sensing learners are concrete thinkers and tend to like learning facts and procedures.

[1] Adapted from the ILS website, http://www4.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/styles.htm, and Felder & Spurlin (2005).

Intuitive learners are more abstract thinkers and are oriented to theories and prefer discovering possibilities and underlying relationships.

Visual or Verbal Modality

Visual learners remember best things that are represented in a visual format, such as pictures, diagrams, flow charts, time lines, films and demonstrations.
Verbal learners get more out of words prefer written and spoken explanations.

Sequential or Global Modality

Sequential learners tend to understand best by learning the material in small incremental steps, with each step following logically from the previous one.
Global learners tend to appreciate learning through a holistic learning process and often learn in large leaps, absorbing material almost randomly without seeing connections, and then suddenly "getting it."

Appendix C: Factor Analysis of Self-Efficacy and Student Engagement Variables

Factor Analysis of Self-Efficacy Questions

In the end-of-term survey in both years, 30 questions were asked about students' level of confidence in various aspects of learning in the course and in studying engineering in general (*n*=160 in 2012 and *n*=166 in 2013). The 10 questions associated with studying engineering were taken directly from the Longitudinal Assessment of Engineering Self-efficacy instrument (Marra, Rodgers, Shen & Bogue, 2009), while the other 20 were developed for this study.

Principal components analysis using polychoric correlation was conducted to identify the factors underlying the 30 self-efficacy questions. As the correlations among factors were above the threshold of .32 suggested by Tabachnick and Fiddell's (2007), the oblique oblimin was chosen as the rotation method. Note that because the 2013 survey contained extra questions about the inverted classroom experience, Q26 from the 2012 survey was equivalent to Q43 from the 2013 survey. All the questions that followed were identical in both surveys.

Table C-1: Rotated Factor Loadings (Pattern Matrix) for Traditional and Inverted Cohort Data

	Traditional Cohort (2012)				Inverted Cohort (2013)		
	Factor 1	Factor 2	Factor 3		Factor 1	Factor 2	Factor 3
Q26		.422		Q43		.404	
Q27	.423		-.432	Q44			
Q28	.561			Q45	.598		
Q29			.634	Q46			.647
Q30			.820	Q47			.820
Q31			.709	Q48			.773
Q32			.726	Q49			.711
Q33	.400		.418	Q50	.454		.476
Q34			.649	Q51			.700
Q35	.676			Q52	.617		
Q36	.648			Q53	.652		
Q37	.828			Q54	.824		
Q38	.805			Q55	.840		
Q39	.790			Q56	.636		
Q40	.816			Q57	.734		
Q41	.713			Q58	.765		
Q42	.916			Q59	.876		
Q43	.909			Q60	.888		
Q44	.888			Q61	.905		
Q45	.814			Q62	.889		
Q46	.899			Q63	.866		

	Traditional Cohort (2012)				Inverted Cohort (2013)		
	Factor 1	Factor 2	Factor 3		Factor 1	Factor 2	Factor 3
Q47		.755		Q64		.733	
Q48		.530		Q65		.578	
Q49		.788		Q66		.564	
Q50		.783		Q67		.445	
Q51		.914		Q68		.587	
Q52		.685		Q69		.637	
Q53		.821		Q70		.733	
Q54		.602		Q71		.817	
Q55		.671		Q72		.795	
Q56		.654		Q73		.746	

Note. 1. Factor loadings <.4 are suppressed.
2. Those question items loaded onto the same factor in both years are being highlighted.

For the traditional cohort, initial eigenvalues indicated that the first three factors explained 49.61%, 10.59% and 5.20% of the variance respectively. For the inverted cohort the first three factors explained 45.92%, 12.85% and 5.05% of the variance respectively.

The rotated factor loadings were basically consistent across the two years of data, with the exception of Question 44 (or Q27 in 2012), which was excluded in creating factor scores.

Table C-2 shows the question items that were attached to each of the three generated factors, and Table C-3 summarizes the descriptive statistics for these three factors.

Table C-2: Three Factors Indicative of Students' Self-Efficacy and their Related Question Items

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)	Q45. I have a good understanding of the basic concepts of electric and magnetic fields. Q52. 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. Q53. I can clearly explain the essential concepts of how electric and magnetic fields behave to a grade 9 high-school student. Q54. I can clearly explain the essential concepts of how electric and magnetic fields behave to another second-year ECE student. Q55. I can clearly explain the essential concepts of how electric and magnetic fields behave to an ECE professor. Q56. I can clearly explain the basic relationship between **electric** fields and their sources (charges) to another second-year ECE student. Q57. I can clearly explain how **electric** fields interact with materials, such as conductors and insulators, to another second-year ECE student. Q58. I can clearly explain how **electric** fields interact with materials, such as conductors and insulators, to another second-year ECE student.

Factors	Question items
	Q59. I can clearly explain the basic relationship between **magnetic** fields and their sources (currents) to another second-year ECE student. Q60. I can clearly explain how **magnetic** fields interact with materials, such as iron, to another second-year ECE student. Q61. 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. Q62. 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. Q63. 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)	Q43. I will succeed (earn an A or B) in ECE221H1S: Electricity and Magnetism. Q64. I can succeed in an engineering curriculum. Q65. I can succeed in an engineering curriculum while not having to give up participation in my outside interests (e.g. extracurricular activities, family, sports). Q66. I will succeed (earn an A or B) in my physics courses. Q67. I will succeed (earn an A or B) in my math courses. Q68. I will succeed (earn an A or B) in my engineering courses. Q69. I can complete the math requirements for my engineering major. Q70. I can excel in my engineering major during the current academic year. Q71. I can complete any engineering degree at this institution. Q72. I can complete the physics requirements for my engineering major. Q73. I can persist in engineering during the current academic year.
Self-Efficacy Factor 3 Self-efficacy in learning the course material 6 questions Cronbach's alpha = .90 (2012 data) and .87 (2013 data)	Q46. I can draw or visualize a three dimensional picture based on the word description of the problem. Q47. I can determine the appropriate differential length, surface, or volume element (*dl*, *ds*, or *dv*) needed to solve the problem. Q48. I can evaluate the required line, surface, or volume integral needed to solve the problem. Q49. I can do the vector mathematics required for these types of problems (e.g., addition, subtraction, working with unit vectors, and coordinate system conversions). Q50. I can create a clear plan to solve this type of problem before I write down or use any formulas or equations. Q51. I can use the required vector calculus operators (i.e., curl, gradient, and divergence) in the three main coordinate systems to solve the problem.

Table C-3: Descriptive Statistics for the Three Self-Efficacy Factors

Three Self-Efficacy Factors	Traditional Cohort		Inverted Cohort	
	n	Mean (SD)	*n*	Mean (SD)
Self-efficacy in explaining course concepts to others	163	4.56 (1.26)	170	4.43 (1.28)
Self-efficacy in studying engineering	160	5.10 (1.12)	166	5.14 (1.04)
Self-efficacy in learning the material in this course	165	5.22 (1.09)	173	5.22 (.95)

Factor Analysis of Student Engagement Questions

In both years, the end-of-term survey asked 18 questions about students' techniques for studying course materials (*n*=166 in 2012; *n*=174 in 2013).

Factorability was examined in light of the recognized criteria (Tabachnick & Fidell, 2007). The Kaiser-Meyer-Olkin measure of sampling adequacy was .65 in 2012 and .73 in 2013, above the commonly recommended value of .6, and Bartlett's test of sphericity was significant (χ^2 (153) = 617.47, p < .001 in 2012; χ^2 (153)=844.42, p < .001 in 2013). The diagonals of the anti-image correlation matrix were also all over .5. Finally, the communalities were all above .3, further confirming that each item shared some common variance with other items. Given these overall indicators, factor analysis was deemed to be suitable for all 18 items.

Principal components analysis was used to identify the factors underlying the 18 questions. As the questions used a three-point scale (i.e., rarely, occasionally and regularly), a polychonic correlation matrix was used to determine their factorability. As the correlation among factors was low (below .2), varimax rotation was used.

In the 2012 data, initial eigenvalues indicated that the first three factors explained 23%, 15% and 11% of the variance, respectively. In the 2013 data, the first three factors explained 28%, 16% and 10% of the variance, respectively. As shown in Table C-4, the factor loading matrices generated from the two years of data were not entirely consistent and cross-loading occurred to a few questions.

To create a consistent composite score from those factors for both years, we decided to retain those question items that were loaded onto the same factor in both years. The other question items were eliminated from contributing to a simple factor structure either because they failed to meet a minimum criterion of having a primary factor loading of .4 or above or because they did not contribute to consistency in creating a factor score in both years. The remaining question items and their related factors are shown in Table C-5.

Table C-4: Rotated Factor Loadings (Pattern Matrix) for the Traditional and Inverted Cohorts

	Traditional Cohort			Inverted Cohort		
Questions	*Factor 1*	*Factor 2*	*Factor 3*	*Factor 1*	*Factor 2*	*Factor 3*
Q18a	0.41			0.49		
Q18b					0.46	
Q18c			0.41			0.53
Q18d			0.68			0.80
Q18e			0.65			0.75
Q18f			0.53			0.58
Q18g		0.61			0.71	0.48
Q18h		0.76			0.75	
Q18i		0.81			0.90	
Q18j		0.78			0.88	
Q18k					0.55	
Q18l	0.48		0.61	0.65		0.54
Q18m	0.52		0.49	0.72		
Q18n	0.63			0.89		
Q18o	0.65					
Q18p	0.78			0.69		
Q18q	0.68			0.52	0.43	
Q18r	0.44	0.46				

Note. 1. Factor loadings <.4 are suppressed.
2. Those question items loaded onto the same factor in both years are being highlighted.

The three factor solution was reasonable because the Cronbach's alpha value decreased if the item was deleted (see Table C-6). An exception was Question 18a in the 2012 data; we decided to keep the question within Factor 1 to maintain the consistency with the structure for 2013 data.

Table C-5: Three Factors Indicative of Student Engagement and their Related Question Items

Question: Please indicate how often you used the following techniques for studying the material in this course.	
Student Engagement Factor 1: Extra efforts in studying	a: Reviewing my lecture notes each day or at least each week l: Attempted questions from the textbook which were *not* part of the assigned problem sets m: Read other course-related materials (internet, other E&M textbooks or E&M outlines, etc.) n: Watched lecture videos from other online sources (for example, Kahn Academy, MIT OpenCourseWare, etc.) p: Discussed the course with other students through some online forum or social networking website q: discussed the course with other students outside of class *Cronbach's alpha = .65 (2012 data) and .67 (2013 data) (6 items)*
Student Engagement Factor 2: Review of posted materials	g: Reviewed the solutions to the problem set questions h: Reviewed the solutions to some of the posted example problems i: Reviewed the solutions to this year's term test and/or midterm j: Reviewed the solutions to past term tests and/or midterms *Cronbach's alpha = .72 (2012 data) and .83 (2013 data) (4 items)*
Student Engagement Factor 3: Problem-solving practice	d: Attempted the textbook (Ulaby) problems on my own before checking the posted solutions e: Attempted the workbook (concept) problems on my own before checking the posted solutions f: Attempted to solve some of the posted example problems before checking the solutions *Cronbach's alpha = .62 (2012 data) and .67 (2013 data) (3 items)*

Table C-6: Comparing Cronbach's Alpha Values with those if the Question Item is Deleted

	Traditional Cohort		Inverted Cohort	
Factor 1	Cronbach's alpha=.65	Alpha if Item Deleted	Cronbach's alpha=.67	Alpha if Item Deleted
	Q18a	0.66	Q35a	0.65
	Q18l	0.61	Q35l	0.63
	Q18m	0.57	Q35m	0.62
	Q18n	0.59	Q35n	0.59
	Q18p	0.58	Q35p	0.61
	Q18q	0.64	Q35q	0.67
Factor 2	Cronbach's alpha=.72		Cronbach's alpha=.83	
	Q18g	0.71	Q35g	0.80
	Q18h	0.62	Q35h	0.78
	Q18i	0.62	Q35i	0.77
	Q18j	0.68	Q35j	0.78
Factor 3	Cronbach's alpha=.62		Cronbach's alpha=.67	
	Q18d	0.40	Q35d	0.50
	Q18e	0.53	Q35e	0.54
	Q18f	0.61	Q35f	0.66

Composite scores were created for those three factors based on the mean of the items which had their primary loadings on each factor. The descriptive statistics for the three factors are shown in Table C-7.

Table C-7: Descriptive Statistics for the three Student Engagement Factors

Student Engagement Factors	Number of Items	Traditional Cohort		Inverted Cohort	
		Mean	*SD*	*Mean*	*SD*
Additional efforts in studying	6	1.51	0.40	1.45	0.39
Review of posted materials	4	2.40	0.49	2.35	0.58
Problem-solving practice	3	1.94	0.55	1.38	0.44

Appendix D: Additional Data

Results from Correlation Analysis for Learning Outcome Measures

Tables D-1 and D-2 present the correlation coefficients for the five learning outcome measures and the three self-efficacy measures for the two cohorts. It shows that for the traditional cohort, all five outcome measures were significantly correlated with each other, with r values ranging from .26 to .77, $p < .01$, with the exception of the association between the CI gain scores and long-term concept retention scores, which had an $r = .01$, $p > .05$. For the inverted cohort, the CI gain scores were not significantly correlated with analytic problem-solving quiz scores ($r = .08$, $p > .05$) or long-term concept retention scores ($r = .24$, $p > .05$). The outcome variables co-varied to a different extent. A stronger relationship was found between the academic problem-solving quiz scores and course academic performance ($r^2 = .59$ and .45 for the traditional and inverted cohorts, respectively) and between the CI post scores and long-term retention scores ($r^2 = .49$ and .59 for the traditional and inverted cohorts, respectively) than between the CI gain scores and course academic performance ($r^2 = .07$ and .05 for the traditional and inverted cohort, respectively).

Table D-1: Correlation Coefficients between Outcomes and Self-Efficacy Measures: Traditional Cohort

Variables	*n*	CI post	CI gain	APSQs	CAP	Long-term	SE -F1	SE - F2	SE -F3
Concept inventory: Post-test score	286	1							
Concept inventory: Gain score	276	$.43^{**}$	1						
Analytic problem-solving quiz score (APSQs)	126	$.54^{**}$	$.26^{**}$	1					
Course academic performance (CAP)	286	$.57^{**}$	$.26^{**}$	$.77^{**}$	1				
Long-term concept retention test score	66	$.70^{**}$	.01	$.58^{**}$	$.45^{**}$	1			
Self-efficacy Factor 1: *Explaining course concepts to others*	160	$.22^{**}$	.14	$.40^{**}$	$.27^{**}$	-.07	1		
Self-efficacy Factor 2: *Studying engineering*	157	$.23^{**}$	.14	$.48^{**}$	$.46^{**}$	.09	$.58^{**}$	1	
Self-efficacy Factor 3: *Learning the course material*	162	$.16^{*}$	.13	$.48^{**}$	$.34^{**}$	.16	$.70^{**}$	$.64^{**}$	1

* $p < .05$; ** $p < .01$

Table D- 2: Correlation Coefficients between Outcomes and Self-Efficacy Measures: Inverted Cohort

Variables	*n*	CI post	CI gain	APSQs	CAP	Long-term	SE -F1	SE - F2	SE -F3
Concept inventory: Post-test score	314	1							
Concept inventory: Gain score	297	.42**	1						
Analytic problem-solving quiz scores (APSQs)	113	.53**	.08	1					
Course academic performance (CAP)	314	.56**	.23**	.67**	1				
Long-term concept retention test score	49	.77**	.24	.50**	.69**	1			
Self-efficacy Factor 1: *Explaining course concepts to others*	167	.52**	.14	.38**	.46**	.50**	1		
Self-efficacy Factor 2: *Studying engineering*	163	.47**	.22**	.39**	.53**	.59**	.53**	1	
Self-efficacy Factor 3: *Learning the course material*	170	.35**	.14	.44**	.41**	.47*	.60**	.67**	1

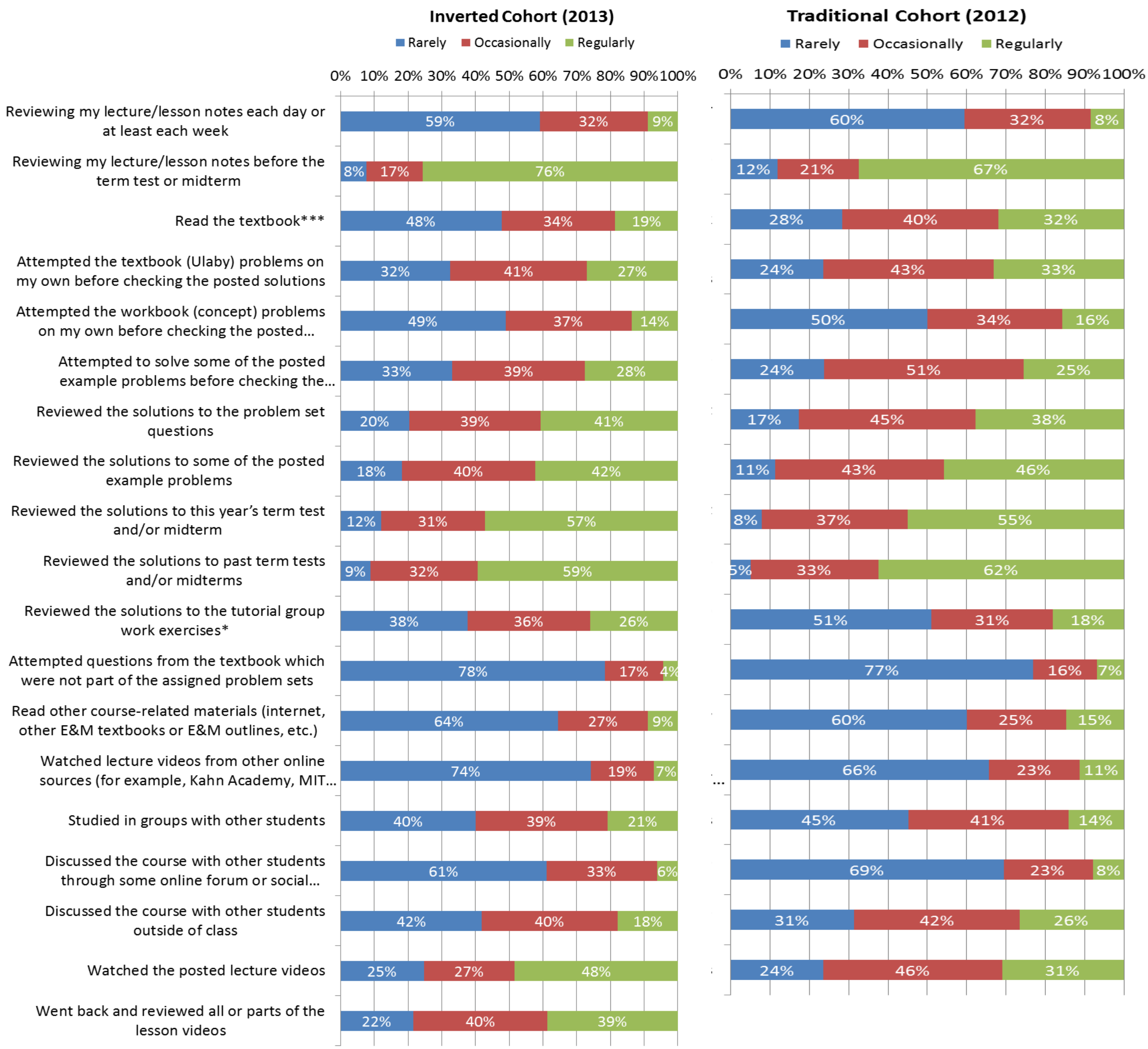
* $p < .05$; ** $p < .01$

The correlations with CI gain scores and long-term retention scores for the three self-efficacy measures were not significant for the traditional cohort, while the correlations were insignificant between the CI gain scores and two self-efficacy measures (1 and 3) only for the inverted cohort. The strengths of the relationships between outcomes and self-efficacy measures differed by student cohort. The relationship between the academic problem-solving quiz scores and the three self-efficacy measures was stronger for the traditional cohort (r^2 = .16 to .23) than for the inverted cohort (r^2 : .14 to .19). In contrast, the relationships of CI post scores and course academic performance with the three self-efficacy scores were stronger for the inverted cohort than for the traditional cohort. The difference was particularly prominent in the relationship between long-term retention scores and self-efficacy measures, with r^2 values between .21 and .34 for the inverted cohort and .01 and .03 for the traditional cohort.

Use of Study Techniques

The two figures below summarize students' reported use of various study techniques within the course for the two cohorts. Marked are the two questions that had distributions that differed significantly between the two cohorts (* $p < 0.05$, *** $p < 0.001$).

Figure D-1: Comparisons of Study Techniques



Appendix E: End-of-Term Course Survey (2013)

ECE221H1S: Electric and Magnetic Fields
Course Survey April 2013

The purpose of this survey is to assess your learning experience within ECE221H1S: Electric and Magnetic Fields. This survey is part of a larger research project which will aim to assess the relative effectiveness of a new teaching approach. It is only through your participation that this project will be successful and lead to useful conclusions, so your support and honest assessment is greatly appreciated. It is our hope that with the participation of the majority of students in ECE221H1S, we will be able to continue to work to improve the student experience within our faculty. It should take you about 15 minutes to complete the survey.

Please be assured that your responses to this survey will be confidential and will, in no way, affect your grades of the course. The data will be accessible only to the research associate (Siddarth Hari), and only anonymous data will be reported to the Principal Investigator of the study (Dr. Micah Stickel).

At the beginning of the term you asked to become a participant in this larger research study. As part of that request you were given a letter which outlined the details of the project and what it meant to be a participant in this research (Letter of Informed Consent). If have not yet had the opportunity to provide your informed consent to become a participant you can do so now if you wish:

- ❍ By checking here, I voluntarily agree to take part in this study which has been described in the informed consent letter provided to me earlier in the term.

Your name: ______________________________________
(Please **PRINT** your first and last name.)

Your student number: ____________________________
Your major or intended major as of today (Check one):

❍ Electrical Engineering ❍ Computer Engineering ❍ Undecided

Students' Preferences

Please indicate to what extent you agree or disagree with the following statements **about the course ECE221**.

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
1. The lectures in this course were very helpful to me in developing my understanding of the course material	❍	❍	❍	❍	❍	❍	❍
2. The tutorials in this course were very helpful to me in developing my understanding of the course material	❍	❍	❍	❍	❍	❍	❍
3. The computer lab experiences in this course were very helpful to me in developing my understanding of the course material	❍	❍	❍	❍	❍	❍	❍
4. The conceptual (workbook) questions on the problem sets were very helpful to me in developing my understanding of the course material	❍	❍	❍	❍	❍	❍	❍
5. The textbook (Ulaby) questions on the problem sets were very helpful to me in developing my understanding of the course material	❍	❍	❍	❍	❍	❍	❍
6. The readings from the textbook were very helpful to me in developing my understanding of the course material	❍	❍	❍	❍	❍	❍	❍
7. The lecturing approach that the instructor took was effective in helping me learn the material in the course	❍	❍	❍	❍	❍	❍	❍
8. Overall, I was quite engaged with this course throughout the term	❍	❍	❍	❍	❍	❍	❍
9. I can see how the material covered by this course is important to know for an electrical or computer engineer	❍	❍	❍	❍	❍	❍	❍
10. Compared to the other courses that I have taken in my second year, the amount of work required for this course is reasonable	❍	❍	❍	❍	❍	❍	❍
11. Overall, I enjoyed taking the course	❍	❍	❍	❍	❍	❍	❍

12. During the ***lectures***, I usually:

- ❍ Took notes using the posted lecture outlines.
- ❍ Took all my own notes.
- ❍ Did not take notes at all.
- ❍ I did not attend any of the lectures.

13. The number of ***lectures*** that I missed over the course of the term was:

- ❍ None
- ❍ 1 to 5
- ❍ 6 to 10
- ❍ 11 to 15
- ❍ 16 to 20
- ❍ More than 20 (over half of them)

14. The primary reason why I missed the lectures that I did, was:

- ❍ I was too far behind in the course, so I did not understand what was being talked about.
- ❍ I had too much other work to do.
- ❍ I did not find them helpful.
- ❍ They were too early in the morning.
- ❍ I was sick.
- ❍ I never missed a lecture.
- ❍ Other (please describe the primary reason)

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15. When I watched the ***lesson videos***, I usually:

- ❍ Took notes using the posted lesson outlines.
- ❍ Took my own notes.
- ❍ Did not take notes, but I focused on trying to understand the material.
- ❍ I did not pay much attention to the video as it played.

16. Most of the time, I watched the ***lesson videos***:

- ❍ At home or in my residence room.
- ❍ In one of the computer labs.
- ❍ On a mobile device.
- ❍ Other (please describe)

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Please indicate to what extent you agree or disagree with the following statements **about the lesson videos**.

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
17. The lesson videos were an effective introduction to the main concepts covered in the course	❍	❍	❍	❍	❍	❍	❍
18. The lesson videos effectively prepared me for the lectures which followed	❍	❍	❍	❍	❍	❍	❍
19. The lesson videos were interesting	❍	❍	❍	❍	❍	❍	❍
20. The quizzes that were embedded in the videos were very helpful to me in developing my understanding of the course material	❍	❍	❍	❍	❍	❍	❍
21. The length of the lesson videos was appropriate	❍	❍	❍	❍	❍	❍	❍
22. The process of accessing and viewing the videos worked well for me.	❍	❍	❍	❍	❍	❍	❍

In comparing the “inverted classroom approach” that was used in ECE221, with courses that you have had which were taught using the “traditional” lecturing approach, how would you answer the following questions:

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
23. Overall, the inverted classroom approach allowed me to make effective use of my time to develop my understanding of the course material.	❍	❍	❍	❍	❍	❍	❍
24. The inverted classroom approach made the in-class time more useful in developing my understanding of the course material.	❍	❍	❍	❍	❍	❍	❍
25. The inverted classroom approach made the in-class time more enjoyable.	❍	❍	❍	❍	❍	❍	❍

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
26. With the inverted classroom approach I did not have to “cram”, or catch up as much as I normally would have had to before the term test and the midterm.	❍	❍	❍	❍	❍	❍	❍
27. I feel that I was given all the support I needed in this course to learn the material well.	❍	❍	❍	❍	❍	❍	❍
28. I feel that I had the opportunity to get all of my questions about the material answered (i.e., in class, with the instructor, on CoursePeer, etc.)	❍	❍	❍	❍	❍	❍	❍
29. In comparison with the traditional lecturing approach, I prefer the inverted classroom approach	❍	❍	❍	❍	❍	❍	❍
30. Overall, the inverted classroom approach in this course has provided me with an effective learning experience	❍	❍	❍	❍	❍	❍	❍

31. How could the inverted classroom approach be improved?

Students’ Personal Interactions, Engagement, and Perceptions

32. 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
During class	❍	❍	❍	❍	❍	❍
Immediately after class	❍	❍	❍	❍	❍	❍
During the instructor’s office hours	❍	❍	❍	❍	❍	❍
Outside the class (e.g., hallway conversation)	❍	❍	❍	❍	❍	❍

33. 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:

	Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
During class	❍	❍	❍	❍	❍
Immediately after class	❍	❍	❍	❍	❍
During the instructor's office hours	❍	❍	❍	❍	❍
Outside the class (e.g., hallway conversation)	❍	❍	❍	❍	❍

34. Overall, the level of my personal interaction with the instructor for ECE221 this term was:

- ❍ Very adequate
- ❍ Adequate
- ❍ Somewhat adequate
- ❍ Not at all adequate

35 Please indicate how often you used the following techniques for studying the material in this course.

	Rarely	Occasionally	Regularly
Reviewing my lecture/lesson notes each day or at least each week	❍	❍	❍
Reviewing my lecture/lesson notes before the term test or midterm	❍	❍	❍
Read the textbook	❍	❍	❍
Attempted the textbook (Ulaby) problems on my own before checking the posted solutions	❍	❍	❍
Attempted the workbook (concept) problems on my own before checking the posted solutions	❍	❍	❍
Attempted to solve some of the posted example problems before checking the solutions	❍	❍	❍
Reviewed the solutions to the problem set questions	❍	❍	❍
Reviewed the solutions to some of the posted example problems	❍	❍	❍
Reviewed the solutions to this year's term test and/or midterm	❍	❍	❍
Reviewed the solutions to past term tests and/or midterms	❍	❍	❍
Reviewed the solutions to the tutorial group work exercises	❍	❍	❍
Attempted questions from the textbook which were *not* part of the assigned problem sets	❍	❍	❍
Read other course-related materials (internet, other E&M textbooks or E&M outlines, etc.)	❍	❍	❍
Watched lecture videos from other online sources (for example, Kahn Academy, MIT OpenCourseWare, etc.)	❍	❍	❍

	Rarely	Occasionally	Regularly
Studied in groups with other students	❍	❍	❍
Discussed the course with other students through some online forum or social networking website	❍	❍	❍
Discussed the course with other students outside of class	❍	❍	❍
Watched the posted ***lecture*** videos	❍	❍	❍
Went back and reviewed all or parts of the ***lesson*** videos	❍	❍	❍

36. Did you use other techniques for studying the material in this course? If so, please specify.

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37. Which of the following statements best describes your engagement with the course material?
    - ❍ I would review the material before it was covered in the lectures
    - ❍ I would review the material (i.e., read the textbook and review class notes) each week
    - ❍ I waited until shortly before the term test or the midterm to review the material (i.e., read the textbook and review class notes)
    - ❍ I never felt that I was caught up with the course material

38. If you had to rank the courses taken this term (in order of how much you liked taking them), where would you place ECE221?
    - ❍ 1 (Liked the most)
    - ❍ 2
    - ❍ 3
    - ❍ 4
    - ❍ 5 (Liked the least)

39. In terms of supporting your learning of the course material, what was the most useful aspect of the classroom experience (i.e., the lectures)?

40. How could the classroom experience (i.e., the lectures) be improved?

41. What about this course did you really like?

42. How could this course be improved?

Confidence with the Course Material and Thoughts About Studying Engineering

Please indicate to what extent you agree or disagree with the following statements **on your level of confidence relating to the course material of ECE221**.

	I am confident that as of now…	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
43.	I will succeed (earn an A or B) in ECE221H1S: Electricity and Magnetism	❍	❍	❍	❍	❍	❍	❍
44.	I can learn the material in this course	❍	❍	❍	❍	❍	❍	❍
45.	I have a good understanding of the basic concepts of electric and magnetic fields	❍	❍	❍	❍	❍	❍	❍

	For a typical electric and magnetic fields problem I am confident that as of now…	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
46.	I can draw or visualize a three-dimensional picture based on the word description of the problem	❍	❍	❍	❍	❍	❍	❍
47.	I can determine the appropriate differential length, surface, or volume element (*dl*, *ds*, or *dv*) needed to solve the problem	❍	❍	❍	❍	❍	❍	❍
48.	I can evaluate the required line, surface, or volume integral needed to solve the problem	❍	❍	❍	❍	❍	❍	❍

	For a typical electric and magnetic fields problem I am confident that as of now…	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
49.	I can do the vector mathematics required for these types of problems (e.g., addition, subtraction, working with unit vectors, and coordinate system conversions)	❍	❍	❍	❍	❍	❍	❍
50.	I can create a clear plan to solve this type of problem before I write down or use any formulas or equations	❍	❍	❍	❍	❍	❍	❍
51.	I can use the required vector calculus operators (i.e., curl, gradient, and	❍	❍	❍	❍	❍	❍	❍

	divergence) in the three main coordinate systems to solve the problem							
52.	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 am confident that as of now…	**Strongly Disagree**	**Disagree**	**Slightly Disagree**	**Neither Agree nor Disagree**	**Slightly Agree**	**Agree**	**Strongly Agree**
53.	I can clearly explain the essential concepts of how electric and magnetic fields behave to a grade 9 high-school student	❍	❍	❍	❍	❍	❍	❍
54.	I can clearly explain the essential concepts of how electric and magnetic fields behave to another second-year ECE student	❍	❍	❍	❍	❍	❍	❍
55.	I can clearly explain the essential concepts of how electric and magnetic fields behave to an ECE professor	❍	❍	❍	❍	❍	❍	❍
56.	I can clearly explain the basic relationship between **electric** fields and their sources (charges) to another second-year ECE student	❍	❍	❍	❍	❍	❍	❍
57.	I can clearly explain how **electric** fields interact with materials, such as conductors and insulators, to another second-year ECE student	❍	❍	❍	❍	❍	❍	❍
58.	I can clearly explain how **electric** fields are applied to solve engineering problems (i.e., through capacitance, energy storage, etc.) to another second-year ECE student	❍	❍	❍	❍	❍	❍	❍
59.	I can clearly explain the basic relationship between **magnetic** fields and their sources (currents) to another second-year ECE student	❍	❍	❍	❍	❍	❍	❍

	I am confident that as of now…	**Strongly Disagree**	**Disagree**	**Slightly Disagree**	**Neither Agree nor Disagree**	**Slightly Agree**	**Agree**	**Strongly Agree**
60.	I can clearly explain how **magnetic** fields interact with materials, such as iron, to another second-year ECE student	❍	❍	❍	❍	❍	❍	❍

61. 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	❍	❍	❍	❍	❍	❍	❍
62. 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	❍	❍	❍	❍	❍	❍	❍
63. I can clearly explain how **time-varying electromagnetic** fields can be applied (i.e., through transformers, etc.) to another second-year ECE student	❍	❍	❍	❍	❍	❍	❍

Please indicate to what extent you agree or disagree with the following statements **<u>about studying engineering</u>**.

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
64. I can succeed in an engineering curriculum	❍	❍	❍	❍	❍	❍	❍
65. I can succeed in an engineering curriculum while <u>not</u> having to give up participation in my outside interests (e.g. extracurricular activities, family, sports)	❍	❍	❍	❍	❍	❍	❍
66. I will succeed (earn an A or B) in my physics courses	❍	❍	❍	❍	❍	❍	❍
67. I will succeed (earn an A or B) in my math courses	❍	❍	❍	❍	❍	❍	❍
68. I will succeed (earn an A or B) in my engineering courses	❍	❍	❍	❍	❍	❍	❍
69. I can complete the math requirements for my engineering major	❍	❍	❍	❍	❍	❍	❍
70. I can excel in my engineering major during the current academic year	❍	❍	❍	❍	❍	❍	❍
71. I can complete any engineering degree at this institution	❍	❍	❍	❍	❍	❍	❍

72.	I can complete the physics requirements for my engineering major	❍	❍	❍	❍	❍	❍	❍
73.	I can persist in engineering during the current academic year	❍	❍	❍	❍	❍	❍	❍

Thank You Very Much!

Higher Education Quality Council of Ontario

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