The effect of interactive lecture experiments on student academic achievement and attitudes towards physics

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Abstract: This paper examines the effects of computer-based Interactive Lecture Experiments (ILEs) in a large introductory physics course on student academic achievement and attitudes towards physics. ILEs build on interactive lecture demonstrations by requiring students to analyze data during and after lecture demonstrations. Academic achievement was measured using the Force Concept Inventory (FCI) and final examinations' grades; and student attitudes were measured using a Colorado Learning Attitudes about Science Survey (CLASS). FCI results showed a general positive shift (about average for an interactive course) but could not detect improvements in student understanding of specific topics addressed by ILEs. However, open-ended questions on the final exam showed differences between sections on topics that were addressed by ILEs. Attitude survey results showed a negative shift in student attitudes over the semester, which is a typical result for an introductory physics course. This finding suggests that ILE pedagogy alone is insufficient to significantly improve student attitudes toward science. The study also revealed possible improvements to implementing ILEs such as working in groups, ongoing feedback for students, and linking assessment to pedagogical practices.

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Résumé : Nous examinons ici les effets d'une Expérience de Cours Interactif avec ordinateur (ILEs) sur les résultats académiques et l'attitude envers la physique d'un grand groupe d'étudiants qui suivent un cours d'introduction à la physique. ILE utilise des démonstrations interactives en classe et requiert que les étudiants analysent les données pendant et après la classe. Nous avons mesuré la performance académique en utilisant une technique connue sous le nom de « Force Concept Inventory » (FCI) ou Fonds des Concepts de Force (comment les étudiants conçoivent, visualisent la force mécanique) et sur les résultat de l'examen final. L'attitude des étudiants a été mesurée en utilisant l'outil CLASS développé au Colorado. Les résultats FCI ont montré un déplacement général positif (normal pour un cours interactif), mais n'ont détecté aucune amélioration dans la compréhension que les étudiants ont des différents sujets discutés dans les cours avec pédagogie ILEs. Cependant, les questions ouvertes dans l'examen final ont montré des différences entre les différentes sections pour les sujets étudiés par ILEs. L'analyse des attitudes a montré un déplacement négatif dans les attitudes des étudiants sur la durée de la session, un résultat typique pour un cours d'introduction en physique. Ces résultats indiquent que la pédagogie ILE à elle seule est incapable d'améliorer significativement l'attitude des étudiants envers la science. L'étude révèle également des pistes pour une amélioration possible de ILE, comme le travail en groupe, la contre-réaction en continu et un meilleur lien entre l'évaluation et les pratiques pédagogiques.

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Introduction

Demonstrations have always played an important role in science teaching. However, when observed passively, they often have a limited effect on student learning [1, 2]. Students frequently misinterpret the results or incorrectly remember what happened [3]. Interactive Lecture Experiments (ILEs) have been developed to address this problem [4]. This pedagogy facilitates a greater student engagement with demonstrations and promotes conceptual understanding. Several physics education research projects have focused on the design and implementation of various *active learning environments* aimed to stimulate student learning and satisfaction with physics courses [5–9].

Researchers evaluating the use of educational innovations in introductory physics courses often use Force Concept Inventory (FCI) [10] and Force and Motion Conceptual Evaluation (FMCE) [11] to measure cognitive gains. The standardization of these evaluation tools has had a significant impact on introductory physics teaching because of the ease of application, ability to diagnose student misconceptions and to promote dialogue between instructors and students [12]. Recently, the research focus has widened to recognize the role of attitudes and beliefs in shaping student learning, motivation, and decision making in physics [13]. Attitudes have been shown to depend on gender [14] and age [15]. Students' attitudes are closely linked to motivation and course choice, especially among secondary students. This is a critical issue since enrollment in secondary science courses is the most significant indicator of choosing science

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Table 1. ILEs and course sections.

ILE	Section 101	Section 102	Section 103
ILE1: 1-D kinematics	Yes	Yes	No
ILE2: 2-D kinematics	Yes	No	Yes
ILE3: Static and kinetic friction	Yes	No	Yes
ILE4: Apparent weight	No	Yes	Yes
ILE5: Circular motion	Yes	Yes	No
ILE6: Tension in a pendulum	No	Yes (in groups)	Yes

as a career [16]. Particularly relevant to college teaching are results indicating that students' expectations and academic self-concept were more significant predictors of success in chemistry than their prior achievement and experience [17].

The Colorado Learning Attitudes about Science Survey (CLASS) [18] builds on work from existing surveys such as the Maryland Physics Expectation Survey [19] and Views about Science Survey [20]. It was designed to probe students' beliefs about physics and learning physics and to distinguish the beliefs of experts from those of novices. Being carefully designed and validated, CLASS aims to address a wide variety of issues concerning learning physics through clear concise statements that can be implemented quickly and easily.

Interactive lecture experiments

The development and implementation of ILEs has been described in detail in an earlier paper [3]. In the fall of 2005 several ILEs were developed and piloted in an algebra-based course (Physics 100) at the University of British Columbia. The ILE pedagogy consists of five stages. (1) The demonstration is conducted in a lecture. (2) It is video taped and the data are collected with Vernier computer probes [21] and shared with the students via the course web site. (3) The students carry out data analysis using Logger *Pro* software. Analysis questions focus on physics concepts and the ability of students to support qualitative descriptions with quantitative results. Analysis is assigned as individual homework or as a group project. (4) At the following lecture, analysis questions are discussed and the students are asked to participate using the electronic response system or by submitting brief written reports. (5) The students are also given problem solving tasks (for homework, in class, or on exams), which require the application of concepts and skills addressed by ILEs; these include not only key physics concepts but data processing, error analysis, and curve-fitting skills.

After piloting the technique in 2005–2006, six ILEs were developed for the following year and were part of the current study. (Please contact the authors for access to ILE files.) This work summarizes the effects of ILE pedagogy on student academic achievement and attitudes towards science.

Methodology

The teaching intervention, ILEs, was introduced into a large, algebra-based introductory physics course at the University of British Columbia. The 700 students enrolled in the course were split into three sections, each taught by a different lecturer. The students in this course have only taken one introductory physics course in high school and required a physics credit to complete a Bachelor of Science. The course involved 3 h of large group lectures, 2 h of weekly tutorial, and a 3 h laboratory biweekly. The course ran for 13 weeks. In addition to ILEs, students were assigned online interactive homework questions via Mastering Physics [22] and received lecture participation marks for using an electronic response system. There were two midterms and a final exam. One of the midterms and the final exam were common between all three sections.

To examine the effect of the ILE pedagogy on student conceptual understanding, 4 out of 6 possible ILEs were conducted in each course section. In sections where a topic was not covered by an ILE, a more traditional method was used. Thus, the same topics were discussed with all students, but only four topics were addressed using ILEs (Table 1) in each section. On the final exam, student performance on questions targeting ILE topics was examined for differences between the sections. Student conceptual gain was assessed by in-class pre and post FCI tests [10], administered using electronic response system technology, for which the students were awarded participation marks. Every student received a full mark for taking an FCI pre-test and a mark proportional to their relative gain after they completed an FCI post-test. To make sure the students do not downgrade purposefully their initial FCI performance, the details of the participation mark calculations were announced toward the end of the course. The total mark for the FCI participation amounted to 2% of the final course mark.

Student attitudes were examined using the CLASS [18] instrument, which contains 42 Likert-style statements grouped into eight categories. CLASS was administered at the beginning and the end of the course to measure an attitude shift over the duration of the course. The survey was conducted online and participation was voluntary and anonymous. No marks were assigned for participating. In the post CLASS survey, qualitative questions were also added to probe student opinions and to investigate their attitudes about ILEs as well as their physics-learning experiences.

The study design adheres to ethical research procedures as outlined by UBC's Behavioral Research Ethic Board and was approved in August 2006 (#BO6–0572). All participants signed informed consent forms. Safeguards such as storing personal information separate from data on password protected computers were established.

Results: student achievement

Force concept inventory

Pre and post FCI tests showed significant gains over the semester. Hake's index ($g = \frac{FCI_{\mathrm{post}} - FCI_{\mathrm{pre}}}{100 - FCI_{\mathrm{pre}}}$, where every score was measured in %) was 0.36 ± 0.05 for all students (N = 576). The Hake's index for each section was 0.34 ± 0.05 (N = 177);

Table 2. Average Hake's index for FCI questions that are related to topics addressed by ILEs and those with no direct ILE connection. (N = 651 pre FCI, 576 post FCI).

Topics with ILE connections	FCI question	Average Hake's index (all students)
1-D Motion – ILE 1 (Ball tossed upwards)	1, 2, 3, 13, 14, 19, 20	0.32
2-D Motion – ILE 2 (Ball rolling off the table)	1, 2, 12, 30	0.44
Static and kinetic motion – ILE 3 (Accelerating cart with a block on it)	No FCI connections	
Newton's laws, concepts of weight, apparent weight, normal force – ILE 4 (Jumping on a scale)	17, 25, 26, 27	0.17
Conical pendulum, concepts of circular motion and tension – ILE 5	No FCI connections	
Pendulum, concepts of circular motion and tension - ILE 6	5, 6, 7, 8	0.52
Average Hake's index for ILE related FCI questions: 0.36		
FCI topics with no direct ILE connections		
Impulse and momentum	8, 9, 10	0.29
Newton's third law	15, 16, 28, 29	0.71
Acceleration (2D)	21, 22	0.14
Newton's second law	23, 24	0.27
Average Hake's index for non-ILE related FCI questions: 0.35		

0.43 ± 0.04 (N = 225), and 0.30 ± 0.05 (N = 174) for sections 101, 102, and 103, respectively. Section 102 had a significantly higher FCI gain than Section 101 (p = 0.1) and Section 103 (p = 0.05) when compared using a two-sample t-significance test, while the FCI gains for sections 101 and 103 were not significantly different. For traditional courses the average Hake's index is about 0.23 [8] and in a survey including data sets from 48 interactive courses Hake found that the average gain was 0.48 ± 0.14 with most courses (85%) falling in what he defined as the medium g range ($0.3 \leq g < 0.7$). Thus, for our interactive course the cognitive shift on the concepts tested by the FCI was encouraging, falling in the medium g range but below the average g measured by Hake for a wide range of interactive (but not necessarily large) courses. However, it is important to mention that the differences in Hake's indices of cumulative FCI scores between the sections should not be attributed solely to the ILEs for at least three reasons. First, different ILEs could be linked to the same FCI questions, while some FCI questions were addressed by only one ILE. Second, FCI gains could have also been caused by other course activities such as labs, tutorials, or student homework assignments. Lastly, the sections were taught by different instructors, which also could have caused the differences in the FCI gains.

The Hake's indices for specific FCI questions that were addressed by particular ILEs were calculated for all the students in the course, not just for those who completed these ILEs. It is worth mentioning that such small-question-group FCI comparisons do not have the same large data-base of results that would enable clearer interpretation (as does the use of a gain from the full FCI), but the small-question-group FCI comparisons are being done to try and isolate particular topical areas that may show differential performance. FCI results suggest that conceptual gains were made on some ILE topics (see Table 2) across different sections. For example, the 2-D motion topic, which was addressed by ILEs 2 and 6. All the FCI questions (n = 4) that addressed this topic showed learning gains ranging from 0.30 to 0.58 (average = 0.44). For 1-D motion (ILE 1) the results were less clear. The seven FCI questions on the same topic had Hake's indices that ranged from 0.09 to 0.53 (average = 0.32) with the majority of them falling below the medium g threshold of 0.3. It is important to note that FCI question 1 that has the most direct connection to ILE 1 had a high Hake's index of 0.51. These results indicate that the interactive course design may have contributed to overall learning gains, but there is insufficient evidence to attribute learning gains to a particular course activity such as a specific ILE.

Final examination results

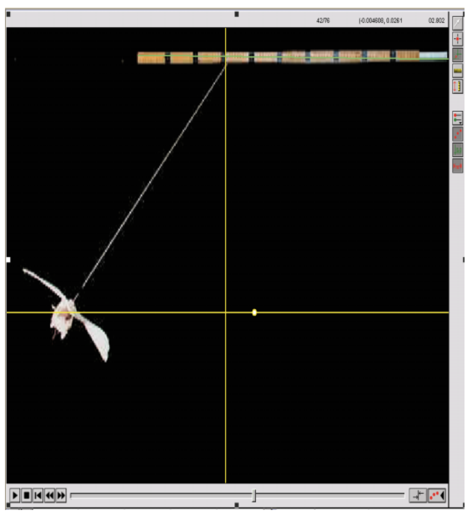
On the final examination, which was common to all students and graded by marking teams using a common rubric, some significant differences were observed on student performance between the sections. Table 3 illustrates the performance of students in each section on open-ended final exam questions. The corresponding ILE and which sections completed the ILE are also indicated in Table 3. See Fig. 1 for a comparison between an open-ended question and an ILE on the same topic. When an analysis of variance (ANOVA) was run to compare the performance of each section on the examination overall Section 102's score out of 45 (27.0 ± 0.6) was significantly higher (p = 0.022) than that of Section 103 (24.4 ± 0.7) but not significantly higher (p = 0.18) than Section 101 (25.3 ± 0.9). Significant differences were found between sections on Question 2 and Question 3 of the final exam, but not on Question 1 and Question 5, even though all of these questions had related ILE activities. Significant differences were calculated using Tukey HSD test post hoc analysis after ANOVA results of $p <$ 0.05 (Fig. 2).

On Question 2 of the final examination (Table 3), Section 102 did significantly better than Section 101 (p = 0.0002) who did not do the ILE and Section 103 (p = 0.000023) who was assigned the ILE but as an individual homework assignment compared to Section 102 who completed the task in groups and submitted a brief report. Therefore, there appears to be significant benefits to assigning ILEs as group

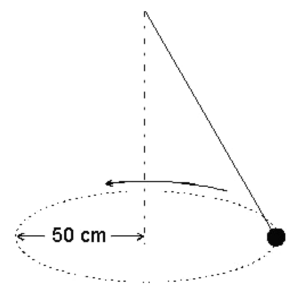
Table 3. Results on final examination open-ended questions for each lecture section and overall include the average mark and the standard error of the mean given in the parentheses. Note that highlighted cells indicate that the section completed the ILE on that topic. Bold type indicates statistically significant differences between sections.

Question	Topic	ILE	Section 101	Section 102	Section 103	All
Q 1	1-D motion	1	43 (3) %	44 (3) %	43 (3) %	43 (2) %
Q 2	Pendulum	6	39 (3) %	**54 (3) %**	34 (3) %	43 (2) %
Q 3	Conical pendulum	5	**62 (3)%**	**59 (2) %**	46 (3) %	56 (1) %
Q 4	Momentum	None	63 (2) %	66 (2) %	72 (2) %	67 (1) %
Q 5	Friction	3	83 (2) %	80 (2) %	80(2) %	81 (1) %
Q 6	DC circuit	None	64 (2) %	68 (2) %	63 (3) %	65 (1) %
Overall			61 (2) %	64 (1) %	60 (2) %	62 (1) %

Fig. 1. Flying pig ILE (conical pendulum) and similar final examination question (Q 3).



A student designs an experiment to demonstrate the motion of a conical pendulum. She attaches a heavy 2.0 kg ball to a 1.0 m long string and kicks it so the ball starts moving along a horizontal circle of radius 50 cm with constant speed, as shown below. Calculate the magnitude of the tension in the string.



projects where students submit reports for formative feedback. On Question 3, which asked students to calculate the tension in a conical pendulum, Sections 101 (p = 0.000039) and 102 (p = 0.00047) who covered this topic using an ILE had significantly better results than Section 103 students who did not complete the ILE. On average, the final examination results indicate that there may be improvements due to using ILEs but this result is certainly based on a small sample of questions and needs to be confirmed with further studies.

Results: student attitudes

Table 4 shows the overall pre and post CLASS results obtained in the current study and compares them to the results from the University of Colorado [18]. The UBC data are displayed for the entire course since there were no significant differences between sections in student attitudes as measured by CLASS and while n = 216 for post test results (see Table 5) only 91 were matched to pre-test results (using anonymous codes generated by the students when they took the tests). The results show that overall, 50% of students agree with experts before completing an introductory physics course at university. Overall and in each category there is a shift towards less expert-like beliefs at the end of the semester, which confirms previously published results [18], but only the shift in sense making and (or) effort is significant.

Other trends in the data are also consistent between our results and previous results. For example, the category with the lowest favourable attitude is applied conceptual understanding for both studies and the highest favorable attitude is sense-making and (or) effort, which means that students know that they need to try hard and attempt to make sense of the problems. The typical results from the Colorado group are on average 17 points higher (for pre-test results) than the UBC results (Table 4). This is attributed, in part, to the fact that we offer different types of courses. The Colorado data are from a calculus-based physics course whereas our data are from an algebra-based course. Adams and her colleagues [18] showed that results from students in courses for physicists and engineers were more expert-like than those in courses for non-scientists. When our data are compared with a more similar course in Colorado (Table 5) the average difference in scores is reduced to 9. This previously unpublished data was supplied by the Physics Education Group at the University of Colorado, Boulder. This consistent difference may be due to differences in how the surveys were collected and to differences in the populations. Our surveys were collected anonymously, voluntarily, and with no marks associated, whereas the Colorado surveys were not anonymous and students received some participation marks for completing them. These are marked differences that significantly affect the response rate. Our numbers only represent a third (216/756) of the students enrolled in the course. The populations of our first year algebra-based

Fig. 2. Overall pre and post CLASS results for UBC students

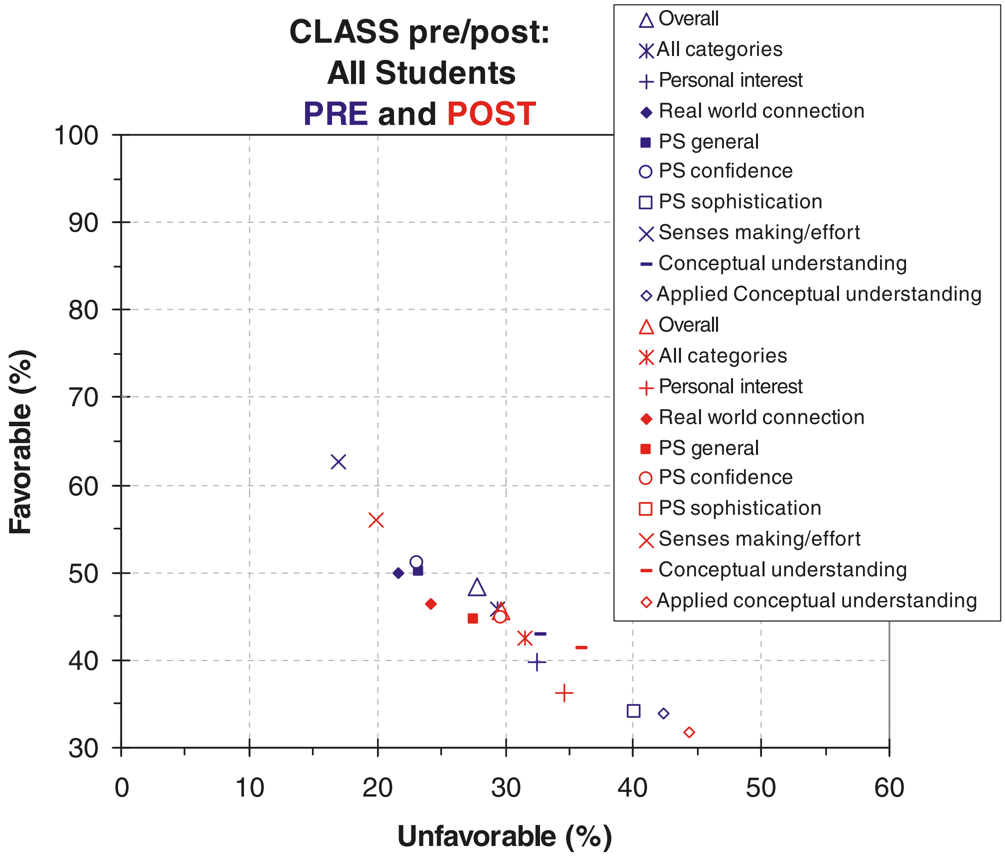


Table 4. Comparison of University of British Columbia (UBC) pre and post CLASS results and results from Colorado group [18]. Percentage of favourable (agree with experts) is shown with the standard error of the mean given in parentheses. Shaded cells represent a significant difference between pre and post responses.

Category	UBC pre	UBC post	Colorado pre	Colorado post
Number of responses	91	91	397	397
Overall	48 (2)	46 (2)	65 (1)	59 (1)
Personal interest	40 (3)	36 (3)	67 (1)	56 (2)
Real world connections	50 (4)	46 (4)	72 (1)	65 (2)
Problem solving general	50 (3)	45 (3)	71 (1)	58 (1)
Problem solving confidence	51 (4)	45 (3)	73 (1)	58 (2)
Problem solving sophistication	34 (3)	28 (3)	61 (1)	46 (2)
Sense-making and (or) effort	63 (3)	56 (3)	73 (1)	63 (1)
Conceptual connections	43 (3)	41 (3)	63 (1)	55 (1)
Applied conceptual understanding	34 (2)	32 (2)	53 (1)	47 (1)

physics courses are also very different. The ethnic diversity at our university is unique with a high proportion of non-native English-speaking students many of whom are not in first year, postponing their required physics credit until the final years of their program. These factors could have significant effects on student attitudes towards science.

Gender differences in CLASS results have been reported [18]. Women are generally less expert-like in statements about real world connections, personal interest, problem-solving confidence, and problem-solving sophistication, and more expert-like in sense-making and (or) effort-type statements. Our data showed no significant differences between genders in the pre CLASS test but some were found in the post CLASS test. Two of the four categories agree with previous results where women scored significantly lower in personal interest and problem-solving sophistication; they were also significantly less expert-like than men on conceptual connections and applied conceptual understanding type statements. In the sense-making and (or) effort category (where women have been shown to score higher) the results were the closest between men and women (54% women and 58% men). These results indicate that both men and women experience a shift to less expert-like beliefs but that women's beliefs shift more drastically.

Table 5. Comparison of UBC and Colorado pre-test CLASS (supplied by W.K. Adams, University of Colorado, Boulder) results for algebra-based Physics 1 courses. The standard error of the mean is given in the parentheses.

Category	UBC pre	Colorado pre
Number	216	310
Overall	50 (1)	58 (1)
Personal interest	44 (2)	49 (2)
Real world connections	53 (2)	62 (2)
PS general	52 (2)	65 (1)
PS confidence	54 (2)	68 (2)
PS sophistication	35 (2)	46 (2)
Sense making and (or) effort	63 (2)	69 (1)
Conceptual connections	43 (2)	54 (2)
Applied conceptual understanding	34 (2)	41 (1)

Qualitative results

When the post CLASS survey was collected we added several open-ended questions and Likert-style questions specifically about ILEs to solicit student comments and opinions (see Appendix for full list of questions). The answers to the Likert-style questions were fairly negative on the whole with the majority of students answering “disagree” or “neutral” to statements such as “Completing Interactive Lecture Experiments helped me improve my problem solving skills”. The only statement that garnered a positive response was the 32% of students who agreed that completing ILEs helped to understand laboratory experiments on the same topic. This is likely because the labs also used Logger *Pro* software, so it was easy for students to see the connections between the two activities. It is disappointing that students responded so negatively to ILEs (41% said that they do not enjoy working on ILEs); many of the comments about ILEs were that they were too time consuming or had technical issues. When asked to rank particular ILEs and give reasons students admitted to finding many of them challenging but also gave affective reasons for their rankings such as: “The flying pig one was funny and cute”, “The more interactive the experiment, the more enjoyable” and “Pigs don’t fly was interesting and appealing.” These types of comments indicate that ILEs are providing students with some entertainment and that completing ILEs is not purely a cognitive experience. Thus, for some students it appears ILEs also address affective aspects of learning.

Student responses about how ILEs should be implemented provided some useful data. After ILEs were assigned students submitted the answers to their individual homework or individually answered questions related to ILEs using the electronic response system. Many students were frustrated with the lack of feedback on their answers to ILE questions when they were collected using the electronic response system technology. “Somehow make it so that the lecture experiments can give you feedback so you know what you’re doing is right or wrong. . .” Statements like this also support findings from the final examination where students who completed the ILE group activity (and submitted a report on which feedback was given) were more successful on the relevant question on the exam than students in other sections who did not submit their ILE results for feedback. Finally, many students commented that ILE questions or topics were not sufficiently represented on exams and were thus a waste of time. “In this course we were given resources such as Mastering Physics which I think is more conceptual and the ILEs which were conceptual once again. Yet, we weren’t given the most basic and important resource which is what the midterms were based on...solving problems...mathematical and graphical problems.” From these kinds of comments we learned, as others have already presented [7, 23], that it is necessary to link ILEs more explicitly to all types of assessment in the course. Suggestions for how to do this are described by the authors in a recent paper [24].

Improving the implementation of ILEs

Results from this study point to ways in which we need to change how the ILEs are incorporated into introductory physics courses. For example, the use of innovative pedagogies must also go hand in hand with revised assessment practices [7, 23, 24]. In addition, although great pains were taken to provide support for students familiarizing themselves with new software such as Logger *Pro,* students needed more technical support.

The strong results on one of the final exam questions by the section of students who worked on the relevant ILE in groups and submitted reports that received detailed feedback indicates that great conceptual gains can be achieved with ILEs. However, ILE effectiveness strongly depends on their implementation, i.e., on the amount, timeliness, and consistency of feedback the students are provided with. Ideally students should work on ILE assignments in groups and receive formative feedback on their results, which can be very challenging in a large class.

Conclusions and discussion

Examination results and positive FCI shifts (about average for an interactive course) indicate that ILEs may contribute to improving student understanding of physics concepts via making the lectures more interactive. However, considering other interactive pedagogies employed in this course such as Mastering Physics, electronic response systems, tutorials, and labs, and the variety of topics addressed by ILEs, the FCI data could not detect improvements in student understanding of specific topics due to ILEs. Open-ended questions on the final examination showed differences on some topics between sections on topics that were addressed by ILEs. This is the strongest evidence that ILEs have the potential to promote learning both of physics concepts and skills through deeper engagement with demonstrations and data. Unfortunately, students do not necessarily recognize these gains, demonstrated by a shift towards less expert-like beliefs on CLASS and from student comments. If interactive methods are seen as additional work on top of the components of a traditional physics course (examinations, labs, homework problems) or if assessment practices do not sufficiently reflect the interactive method [7, 23, 24] student comments may be especially negative.

Adams et al. [18] have shown the detrimental effects of most teaching practices common in large lecture courses. However, they have also demonstrated measurable (positive) effects in courses that explicitly address student beliefs. Students' comments about ILEs hint that for some students completing them, especially in groups, is not a purely cognitive experience but also addresses the affective domain of learning, which can have a positive impact on their attitudes and beliefs towards physics. Provided students see how completing ILEs contributes to their success in the course (both in terms of their marks and in terms of their conceptual understanding), ILEs have a potential of becoming a natural compliment to a course that explicitly addresses student attitudes and beliefs about physics.

Finally, the results of this study have provided the researchers with the necessary information to improve ILE implementation in introductory science courses.

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Appendix A: Open-ended and Likert style questions about Interactive Lecture Experiments

Open-ended questions

Do you think we should use Interactive Lecture Experiments (ILEs) next year? Yes or No. Please explain why or why not you think we should use ILEs next year.

Has your opinion of physics changed? Yes or No. If your opinion did change, please describe how.

Rank the following ILEs from favourite to least favourite. Please give reasons for your rankings.

Describe how you best learn physics and what sorts of activities and resources (lectures, laboratory, assignments etc…) are the most helpful for you.

What suggestions or changes would you make to the ILEs or how they were used in Physics 100?

Estimate how much time you spent (on average) completing an ILE (less than half an hour, half an hour, between half an hour to an hour, between one and two hours, more than two hours).

Likert style questions

Please rank the following statements between 1–5 where:

1 – strongly disagree
2 – disagree
3 – neutral
4 – agree
5 – strongly agree

I feel comfortable with computers and learning new software.

I have a positive attitude towards physics.

I have a positive attitude towards Physics 100 class.

I feel confident that I will be successful in Physics 100 class.

I enjoyed working on Interactive Lecture Experiments.

Working on Interactive Lecture Experiments helped me solve other problems on the same topic.

Completing Interactive Lecture Experiments helped me improve my problem solving skills.

Completing Interactive Lecture Experiments analysis at home was helpful and worth my time.

Completing Interactive Lecture Experiments helped me apply physics concepts to everyday life.

Completing Interactive Lecture Experiments helped me to make connections between physics theories and equations to experiments.

Completing Interactive Lecture Experiments helped me understand laboratory experiments on the same topic.

Completing Interactive Lecture Experiments helped me prepare for the midterms and laboratory tests.

I find Interactive Lecture Experiments to be more useful in helping me understand physics concepts than regular demonstrations.

I am likely to use graphical analysis techniques, similar to those used in Interactive Lecture Experiment analysis, for my studies in the future.