

Assessing *ISLE* Labs as an Enhancement to Traditional Large-Lecture Courses at the Ohio State University

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Abstract. At the Ohio State University (OSU), some laboratory sections were replaced with Investigative Science Learning Environment (*ISLE*) labs during the 3-quarter calculus-based introductory physics sequence this past academic year. The *ISLE* labs have been developed by the PAER Group at Rutgers University; implementation at OSU is discussed, making a direct comparison of OSU students participating in *ISLE* labs with students in pre-existing labs under the same large-lecture instruction. Assessment included diagnostic tests and feedback from a Q-type instrument. The *ISLE* environment focuses on helping students develop scientific abilities, so we also administered a voluntary lab ‘practical exam’ aimed at testing if these abilities were gained by the students in the *ISLE* labs.

Keywords: Q-sort, *ISLE*, Scientific Abilities, Laboratory Assessment

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INTRODUCTION

Many physics departments including at the Ohio State University (OSU) are interested in implementing more Physics Education Research (PER) based activities. One area in which OSU is making changes is the introductory physics laboratories (labs). The purpose of this paper is to discuss the implementation of a PER-based activity as a replacement of existing labs at OSU. The intent is to share what was learned during this implementation, as well as to discuss the results of the implementation.

What are *ISLE* Labs?

At OSU, we chose to implement the Investigative Science Learning Environment (*ISLE*) labs developed by the Rutgers Physics and Astronomy Education Research (PAER) group [1]. At Rutgers, *ISLE* pervades all aspects of the introductory physics classroom, but at OSU only the labs were replaced with *ISLE* activities. *ISLE* labs consist of student-designed observation, testing, and application experiments [2]. Students are given a problem statement and a set of generic guidelines. In one application experiment students are asked to design two different experiments to find the coefficient of static friction between a shoe and a strip of carpet. Instructions include: “List the assumptions you made. How could these affect the result? List sources of experimental uncertainty. How could you minimize them?”

ISLE was developed to help students develop scientific abilities. These include: Representing information, conducting experiments, thinking divergently, collecting and analyzing data, constructing, testing, modifying and ap-

plying relationships and explanations, and being able to coordinate these abilities [3]. The PAER group has developed a detailed set of rubrics; these rubrics are organized by experiment type and address each ability listed above. The rubrics provide explicit reinforcement of the *ISLE* goals. They are used by students for self-assessment, and are used by the Teaching Assistants (TAs) to grade the in-class lab write-ups. Detailed information on *ISLE*, scientific abilities, and the rubrics can be found at the PAER group ‘scientific abilities’ website [4].

Why Implement *ISLE* at OSU?

The existing introductory physics labs at OSU (referred to as the ‘existing labs’ or the non-*ISLE* labs) were developed for the purpose of addressing common misconceptions and explicitly promoting conceptual understanding. However, as measured by the Force Concept Inventory (FCI) [5], normalized gain [6] is low compared to gain achieved by other PER reformed courses (in 2004 it averaged 0.27). Since these labs only aim to develop conceptual understanding, and they are not achieving this goal as measured by the FCI, OSU is considering alternative instructional methods.

ISLE labs have been chosen as an alternative for OSU for the following reasons. They provide students the opportunity to learn valuable skills, and require virtually no new equipment purchases (since existing experiments can be adapted for the *ISLE* format), the teaching load for *ISLE* labs is similar to the existing labs, and they can be adapted to fit any curriculum. With the rubrics developed at Rutgers, there is a clear framework for developing new *ISLE* labs and effectively implementing the

lab goals. Since *ISLE* labs focus on building skills rather than explicitly addressing concepts, the implementation of *ISLE* labs will be considered a success if at minimum they achieve the same conceptual gains as the existing labs and in addition help students gain scientific abilities.

IMPLEMENTATION

ISLE labs were implemented at OSU in the introductory calculus-based physics sequence during the 2004-2005 academic year. In the autumn quarter mechanics course, 5 of 19 lab sections (approximately 10-20 students in each) were taught using *ISLE*, the other sections were taught using the existing manuals. During winter quarter electricity and magnetism (E&M), 5 of 17 lab sections were replaced with *ISLE* labs. Similarly, during the spring quarter waves and modern physics course, 4 of 14 lab sections were replaced. One *ISLE* section each quarter was taught by one of the authors to directly observe the implementation. All other *ISLE* sections were taught by a TA who is uninvolved with PER. Students did not know which sections would use *ISLE* labs when they registered for the course, and the subset of students who participated in *ISLE* labs changed each quarter.

Both labs met once per week for 108 minutes; neither lab required out-of-class work. The experiments covered in both lab types were very similar, with the major difference being that *ISLE* students covered fewer and had to develop the experiments on their own instead of following step-by-step instructions from the existing lab manual. Students in the *ISLE* labs were required to complete an in-class lab write-up which determined their lab grade. Students in the existing labs received points for participation, with their only grade coming from a post-lab quiz. Students were assured that although grading methods were not the same, final lab grades would be shifted so that the average and standard deviation for both lab types would be the same. Students were permitted to switch out of the *ISLE* sections if they did not want to participate; only one student choose to do so.

Implementation at OSU began only 6 weeks after the authors learned about *ISLE*. Many *ISLE* labs from Rutgers and California State University Chico could be quickly adapted for use at OSU. Since *ISLE* labs have very general instructions, and follow a well-defined pattern enhanced by the rubrics, modifying existing labs and writing new *ISLE* labs to match OSU's existing curriculum was not difficult. In addition, TA training took no longer than for the existing labs (30-60 minutes per week).

Initially, *ISLE* students did self-assessment, lab follow-up questions, occasional quizzes, and their write-ups were fully-graded. There was not enough time for students to complete all tasks carefully (lab periods are

one hour shorter than at Rutgers). We eventually used only lab write-ups and self-assessment, and presented the students with 5 relevant sub-rubrics each week (of which we graded any 3). This allowed students to put more thought into each write-up, and also lowered the grading load on the TAs. We also gave only one experiment per lab session, as it took students a considerable amount of time to come up with an experiment and to do the write-up. A feedback questionnaire given during the first quarter helped us decide on these changes.

TESTING THE IMPLEMENTATION

In our assessment of the *ISLE* lab implementation we are primarily interested in the following questions:

1. Do *ISLE* labs improve conceptual understanding?
2. Is the intent of the *ISLE* labs perceived as important by the students?
3. Do *ISLE* students gain scientific abilities?

To address question 1, we gave a diagnostic test to all students during the first and last lab of each quarter. For the mechanics course we gave the FCI and for E&M we gave the Conceptual Survey on Electricity and Magnetism (CSEM) [7]. For the waves and modern physics course there is no corresponding diagnostic, so we used research questions from Wittmann [8], Sadaghiani [9], and Ambrose [10].

To address question 2, students were given a modified version of the Laboratory Program Variables Inventory [11], aimed at assessing perception of lab activities [12]. We also gave the Colorado Learning Attitudes about Science Survey (CLASS) [13]; but the data has not yet been analyzed in detail. To address question 3 we gave a voluntary lab practical described in detail below.

In addition to these assessments, the TAs felt that *ISLE* students worked harder during the *ISLE* labs than students in the existing labs. Students in the existing labs often passively take data and are not motivated to reflect on the experiments unless the TA engages them in dialogue, but *ISLE* students seemed motivated to find a solution to the problem, and often engaged in discussions without prompting from the TA.

Assessing Conceptual Gains

Independent sample t-tests on initial diagnostic test scores from each quarter indicate the *ISLE* and non-*ISLE* students can be directly compared; there is no significant difference ($\alpha = 0.62, 0.70, \text{ and } 0.23$ for the three quarters respectively). In the first quarter, FCI gains were significantly lower for the *ISLE* students. When look-

ing at individual FCI questions, gains for those addressing Newton's 3rd law were lower for *ISLE* students. The *ISLE* lab covering momentum was difficult to adapt due to last-minute equipment problems, which may have affected student performance. When those four questions were removed from the FCI analysis the gains were no longer significantly different ($\alpha = 0.15$). This indicates that had this specific lab not been problematic the FCI gains may have been statistically similar for the two lab types. For the CSEM, gain scores were almost identical. For the waves and modern physics diagnostics *ISLE* students had higher gains, but this result was not significant. The details and significance levels are given in Table 1.

TABLE 1. Conceptual gains for each quarter.

	FCI	CSEM	Waves
<i>ISLE</i>	.21	.20	.15
non- <i>ISLE</i>	.27	.20	.12
significance	(.032)	(.96)	(.37)

Implementation of *ISLE* by the developers resulted in high conceptual gains as measured by the FCI and CSEM [2]. However, no difference between OSU's *ISLE* and non-*ISLE* students does not indicate a lack of success. First, we did not expect to replicate these results since we did not implement *ISLE* in other parts of the course. In addition, *ISLE* focuses on teaching scientific abilities while OSU's existing labs focus on developing conceptual understanding. Compound this with the fact that *ISLE* students completed only one experiment per lab, they covered less concepts than students in the existing labs. Therefore statistically similar diagnostic gains indicates that *ISLE* students gained the same conceptual understanding despite focusing on other goals in lab and covering less material than those in the existing labs.

Assessing Student Perceptions

All students in the first quarter mechanics course took the Laboratory Program Variables Inventory (LPVI) adapted from [11]. Students sort 25 descriptive statements covering typical lab activities. In addition, the LPVI was given to students in *ISLE* labs at Rutgers and at Chico. This allows us to directly compare our implementation at OSU with the existing labs, and the *ISLE* courses at the developing institutions.

One important goal of *ISLE* is to have students make their own scientific justifications. It is important students perceive the lab as student-directed in terms of their experimental decisions and conclusions. Some LPVI statements were grouped according to the following categories: student-directed, instructor-directed, and in between. Analysis showed that among OSU labs, only *ISLE*

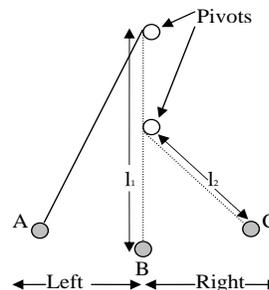


FIGURE 1. Pivoted pendulum from the fake paper.

students perceived the labs as student-directed. In addition, OSU *ISLE* student sortings were similar to those from *ISLE* students at Rutgers and at Chico. These results are discussed in more detail in [12].

Assessing Scientific Abilities

Volunteers solicited to participate in a lab practical were given a fake scientific paper inspired by those in [14]. Two conflicting theories were presented concerning the period of a pendulum as shown in Fig. 1. One stated that since gravity (and therefore acceleration) on both sides is the same, as are the initial and final velocities, the period for each half of the pendulum should be the same. The other stated that the period is proportional to $L^{1/2}$, so cannot be the same for each half of the motion. Students were told they were evaluating a new type of lab, and were not given any information about what to do or how their work would be assessed; they were told only to record anything they felt would be important for making a statement about which theory was correct.

Measurements show the period is not the same, and the period is proportional to $L^{1/2}$ on each side, so in that sense this problem is not difficult. However, this lab practical was designed specifically to test if students gained scientific abilities, so students were not assessed solely on their ability to choose the correct theory, but also on if they were able to design an experiment, analysis, and make a scientific judgment as well as communicate their work clearly. 8 sub-rubrics for testing experiments, 4 from data analysis, and the communication rubric were used for assessment. Students in the *ISLE* labs had previously used the testing experiment rubrics, non-*ISLE* students had not seen the rubrics. Each sub-rubric is graded either 0, 1, 2 or 3, for a total possible score of 39.

28 students participated in the volunteer lab practical; 16 of these students were currently enrolled in an *ISLE* lab section while 12 were not (though 2 of the 12 had previously been in an *ISLE* section). Students worked in groups of two, paired with students in the same treat-

ment group, but handed in individual lab write-ups. Two graders scored the write-ups, then came to a consensus for each student on each sub-rubric. One grader is an author on this paper, while the other is a member of the PAER group, involved with the development of the rubrics at Rutgers, but not involved with the implementation at OSU. Neither grader knew which treatment group to identify with each lab write-up while grading. Two *ISLE* student write-ups were not included in the analysis due to their submission of a correct, but completely theoretical solution to the practical.

There was no difference in grades between the *ISLE* and non-*ISLE* students for the experimental design sub-rubric, as would be expected since the problem itself was simple, and most students came to the correct conclusion that theory two was appropriate. Several *ISLE* students stated the problem to be solved, while only one non-*ISLE* student did this. Half of the *ISLE* students explicitly addressed experimental uncertainty while none of the non-*ISLE* students did. The largest difference between the two groups was from the communication rubric: *ISLE* students averaged 2.21/3, while non-*ISLE* students averaged 1.08/3. The difference in the clarity of the write-ups was striking; with most *ISLE* student write-ups, their experimental design, rationale, and justifications were easy to follow. For most of the non-*ISLE* write-ups it would be very difficult to figure out what they had done without knowing the problem statement. Only 12% of the scores received on any sub-rubric for non-*ISLE* students were a 3, while 20% of *ISLE* students scores were 3. The average sub-rubric score for *ISLE* students was 1.45, while for a non-*ISLE* students it was 1.17. A cross tabulation was performed, and a χ^2 test showed that distribution of scores were significantly different ($\alpha = 0.033$).

The average final grade for *ISLE* students was 18.9 and for non-*ISLE* students it was 15.3. A 2-tailed t-test shows these grades are not quite significantly different ($\alpha = 0.055$). However, a check to determine if the two groups could be directly compared showed that non-*ISLE* volunteers had final course grades (lab plus lecture exam grades) almost one full letter grade higher than the *ISLE* volunteers (there was no significant difference in final course grades over all *ISLE* and non-*ISLE* students). The final course grades were independent of the two lab types since lab grades were normalized as previously described. We recruited heavily from the smaller set of *ISLE* students, so we suspect a broader range were willing to participate, while only the more confident non-*ISLE* students volunteered. With this is taken into account it provides evidence that the *ISLE* students gained scientific abilities during the *ISLE* labs.

CONCLUSIONS

At OSU, existing labs were replaced with *ISLE* labs. They were easy to implement and practical for OSU's introductory course structure. We found that our implementation was successful even though we did not integrate *ISLE* into the lecture goals. Students perceived the *ISLE* labs as student-directed, in contrast to existing labs, which are perceived as instructor-directed. We found evidence that *ISLE* students gain scientific abilities including the ability to better communicate their ideas. We are confident that with more experience, the use of *ISLE* labs will achieve the desired enhancement of the large-lecture course.

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