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Restructuring Introductory Physics by Adapting an Active Learning Studio Model

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Studio teaching, Student-centered learning, Active learning, Force concepts inventory, Conceptual survey of electricity and magnetism, Maryland physics expectations survey, Colorado learning attitudes about science survey

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Introduction

The faculty of the Physics Department at Georgia Southern University has been engaged in a multi-year effort to revolutionize the method by which introductory calculus-based physics is delivered to undergraduate students at our institution. Since the founding of the department in the 1960's introductory courses had been structured as traditional lecture classes (containing approximately 32 students per section) with separate laboratory classes (containing approximately 24 students per section). Each laboratory section was populated by students from various lecture sections of both trig-based and calculus-based physics courses. Originally, the purpose of the laboratory course was to reinforce the material presented in the traditional lecture. As the number of lecture sections increased, it became common for the topics covered in lab to follow a different schedule from the presentations in lecture. With an increase in student demand for courses, students would frequently take the laboratory course during a different semester than the lecture course. Therefore, in practice, the laboratory course had become ineffective in achieving its goal of reinforcing the material presented in lecture. Additionally, faculty became increasingly dissatisfied with lecture as the primary means of instruction despite efforts to engage students in the traditional lecture environment. As the department experienced tremendous growth in introductory courses, due to increases in university student enrollment, discussions began among faculty as to how to address the inadequacies of the existing course structure. Faculty also desired to incorporate many of the modern educational technologies not

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previously available in our department (computer interfaced lab apparatuses, web-based simulations, and classroom response systems) into our introductory courses.

During the fall semester of 2005, faculty developed an interest in offering the introductory courses in a studio format. A studio course seamlessly integrates the lecture and laboratory courses into a single course, devoting much of the class time to active, collaborative, inquiry-based learning. Concepts presented in the lecture can be explicated and reinforced by immediate hands-on laboratory experiences. The characteristics of a studio course include: integration of lecture and laboratory courses, longer and fewer class meetings, increase in student activities emphasizing collaborative and cooperative learning, and shifts in instructor's role from presenter of knowledge to facilitator of learning (Perkins, 2005).

The first pilot studio course was offered in our department during the spring semester of 2006; Table 1 charts the conversion from traditional lecture courses to studio courses from the fall of 2006 to the fall of 2009. Implementation of the studio method was inspired by similar efforts that have taken place at other universities, but differs from these in that introductory physics at Georgia Southern had not previously been taught in a large classroom environment and did not have access to graduate teaching assistants. The pedagogical approach used in the first pilot course closely followed the active-learning format instituted at Rensselaer Polytechnic Institute (Wilson, 1994). This pedagogical approach has been modified and elaborated upon in a number of other physics departments, notably at North Carolina State University's Student-Centered Activities for Large Enrollment – University Physics (SCALE-UP) program (Gaffney, Richards, Kustus, Ding, & Beichner, 2008) and at the Massachusetts Institute of Technology's Technology-Enhanced Active Learning (TEAL) project (Dori, Belcher, Bessette, Danzier, McKinney, & Hult, 2003).

Table 1. Numbers of sections as well as enrollment caps are shown for both traditional lecture and studio classes from the fall semester of 2006 until the fall semester of 2009.

	Calculus-based Physics I		**Calculus-based Physics II**	
	Trad. Sections (Enrollment Cap)	Studio Sections (Enrollment Cap)	Trad. Sections (Enrollment Cap)	Studio Sections (Enrollment Cap)
Fall 2006	4 (32)	1 (24)	3 (32)	1 (24)
Spring 2007	5 (32)	1 (24)	3 (32)	1 (24)
Fall 2007	3 (36)	2 (38)	2 (32)	2 (38)
Spring 2008	4 (36)	2 (42)	2 (36)	2 (38)
Fall 2008		5 (42)		4 (42)
Spring 2009		5 (42)		4 (42)
Fall 2009		5 (48)		4 (48)

Methods

In the spring semester of 2006, the Physics Department offered an experimental section of an integrated lecture/laboratory calculus-based Physics I course in an existing laboratory space with the capacity to seat twenty-four students. The studio course was created without introducing any new courses into the curriculum by using the student registration software to link a single section of a traditional lecture class, meeting three hours per week, with a single section of a laboratory class, meeting two hours per week. This linkage ensured the same students were enrolled in both classes. Additionally, the same instructor was assigned to teach both classes. Most importantly, both classes were taught in the same laboratory space. For the first time in department history, undergraduate teaching assistants assisted with instructional duties, and computer interfaced laboratory equipment was utilized.

The results of the pilot studio course conducted in the spring semester of 2006 were encouraging enough to merit further investigation into adapting the studio active-learning model. The most favorable results were changes in students' attitudes toward learning physics. An open-ended response survey developed by the department was administered to all students enrolled in introductory physics courses. The survey indicated that 90% of all students polled agreed with the following statements: you learn science better with labs integrated into lecture, you learn science better when you are given time in class to collaborate with other students, and you understand science content and concepts better when you conduct your own experiments as you are learning. Due to the positive feedback received from students, the department decided to offer additional studio courses during the next academic year.

The process of modifying the studio method of instruction to accommodate the needs of undergraduate students at our institution was initiated during the summer of 2006. These modifications included replacing traditional lectures with interactive, technology enriched class periods designed around the various learning styles; creating new teaching materials that replaced existing, previously highly-structured laboratory assignments with inquiry-based laboratories relying on computer interfaced laboratory apparatus and web-based computer simulations; and incorporating the use of classroom response systems.

In addition to adapting the studio method of instruction during the summer of 2006, an existing laboratory space was converted into a studio learning environment based on experiences from the pilot course offered during the spring semester of 2006. Tables previously arranged end to end to form long laboratory benches were regrouped in pairs to promote active, collaborate learning. Each pair of tables could accommodate two teams of three students, allowing for a maximum room capacity of forty-eight students. In addition to the chalkboard already in place along one wall of the room, multiple white boards were mounted along the remaining three walls. These chalkboards and white boards would serve as presentation spaces as well as public thinking spaces for the students. The room was equipped with many modern education technologies not previously available in the department. Each student team was equipped with a computer and computer-interfaced laboratory apparatus. The classroom was converted into a "smart" classroom containing two projectors, three pan-tilt-zoom cameras, DVD player, instructor-controllable internet access, and a classroom response system.

During the 2006-2007 academic year, the newly modified calculus-based Physics I and calculus-based Physics II studio courses were implemented. One section of each course was offered during the fall and spring semesters in the newly renovated room with enrollment limited to twenty-four students. Throughout the academic year one instructor taught all sections of Physics I studio, while a second instructor taught all section of Physics II studio.

The photographs in Figure 1 demonstrate the differences in the learning environments between the studio classroom and the traditional lecture classroom. The photo on the left in Figure 1 shows the newly renovated studio classroom during a Physics II class in the fall semester of 2006. After a brief explanation of magnetic fields created by solenoids, using a power point presentation with embedded clicker questions, students were assigned a computer simulation activity to complete in groups. The objectives of this simulation were to develop a visual image of the magnetic field surrounding a solenoid and to understand the dependence of the field inside the solenoid on the current and position. Students were visually able to determine the magnetic field inside of a solenoid is extremely uniform. The last question in the simulation activity required students to derive an expression for the magnetic field along the central axis of an infinitely long solenoid, calculate a hypothetical value for the magnetic field along the central axis of an infinitely long solenoid for a given current value, and compare the calculated value for the infinitely long solenoid with the value for magnetic field along the central axis of the solenoid of finite length in the simulation. Students were amazed by the accuracy of the value of the infinitely long solenoid in predicting the magnetic field along the central axis of solenoid of finite length in the computer simulation.

The photo on the right shows students in a traditional lecture setting studying the same material, on the same day. In the traditional lecture setting, students relied solely on the instructor’s two-dimensional chalkboard drawings to visualize the magnetic field surrounding a solenoid. The derivation of the expression for the magnetic field along the central axis of an infinitely long solenoid was presented by the instructor along with an explanation concerning the expression’s usefulness and limitations in determining the magnetic field along the central axis of a solenoid of finite length. The students were not given the opportunity to physically engage themselves with the presentation of the new material or to collaborate with fellow students due to the limitations of the classroom space and time allowed for the class period.

Figure 1. The photos above show a class taught in the newly renovated studio classroom (left) contrasted with a traditional lecture class (right).

A departmental assessment plan was initiated in the fall semester of 2006 to evaluate the newly adopted student learning outcomes for the studio courses. It became necessary to modify the original goal of the laboratory courses, which was to reinforce the material presented in the traditional lectures, since the concepts presented in the lecture could immediately be explicated in the studio courses through laboratory experiences. The faculty in our department decided to adopt the learning outcomes developed for the

SCALE-UP project at North Carolina State University, these outcomes are as follows: develop a functional understanding of physics; begin developing expert-like problem solving skills; develop laboratory skills; improve communication, interpersonal, and questioning skills; develop technology skills; and develop attitudes that are favorable for learning physics.

Assessment of student learning outcomes was systematically performed throughout the conversion from traditional lecture and laboratory courses into studio courses by administering both pre- and post- content and attitude surveys to students in all sections of introductory courses offered by the department. Students enrolled in Physics I courses completed the Force Concepts Inventory (FCI) and the Maryland Expectations Survey (MPEX). Students enrolled in the Physics II courses completed the Conceptual Survey in Electricity and Magnetism (CSEM) and Colorado Learning Attitudes about Science Survey (CLASS). During the initial pilot studio course in the spring semester of 2006, students in selected sections of the traditional lecture courses and students in the pilot studio course completed the FCI and MPEX assessment surveys as well.

The FCI is a thirty question, multiple-choice exam designed to assess student understanding of the most basic concepts in Newtonian physics (Hestenes, Wells, & Swackhamer, 1992). Typically, student's scores on the FCI are analyzed by calculating the Gain, G. Gains are calculated by using the following formula:

$$G = \frac{(S_{post} - S_{pre})}{(100 - S_{pre})}$$

where S_{post} and S_{pre} are the post-test and pre-test scores, respectively. Average nationwide scores run 25% to 70% for pre-test and 40% to 85% for post-test. Gains of approximately 0.25 are expected for traditionally taught classes; gains in the range of 0.36-0.68 are typical for classes taught interactively (Hestenes & Halloun, 1995).

The CSEM is a thirty-two question, multiple-choice exam designed to assess student's knowledge of topics in electricity and magnetism. Typical pre-test results indicate that students in calculus-based physics courses average 31% of the questions correct; on average post-test results only rise to 47% (Maloney, O'Kuma, Hieggelke, & VanHeuvelen, 2001). To remain consistent with analysis of FCI data, we also calculated gains for the CSEM using the equation given above.

The MPEX survey was developed to explore student attitudes and beliefs about introductory physics courses and to investigate how those attitudes and beliefs change as a result of physics instruction. Students are requested to agree or disagree with thirty-four statements on a five point Likert-scale about how they see physics and how they think and work in a physics course. This survey was constructed to understand student attitudes in six categories: independence (considers his/herself responsible for developing their own understanding), coherence (believes physics must be considered as a connected, consistent framework), concepts (stresses the need to understand the underlying ideas and concepts instead of memorizing and using formulas), reality link (believes concepts learned in physics are relevant and useful in a wide variety of real contexts), math link (believes mathematics is a convenient way of representing physical phenomena), and effort (makes a considerable effort to use information available and tries to make sense of it) (Redish, Steinberg, & Saul, 1998).

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The CLASS is a survey designed to measure student beliefs about physics and about learning physics. This survey extends previous surveys, including the MPEX, by probing additional aspects of student beliefs and by using wording suitable for students in a wide variety of physics courses. Students are again requested to agree or disagree with forty-two statements using a five point Likert-like scale. The survey contains eight categories of questions including: personal interest (feels a personal interest in/connection to physics), real world connection (sees the connection between physics and real life), problem solving general, problem solving confidence, problem solving sophistication, sense making/effort (exerts the effort needed to make sense of the material), conceptual understanding (understands physics is coherent), and applied conceptual understanding (understands and applies a conceptual approach to problem solving, does not memorize or follow problem solving recipes) (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Wieman, 2006). Both the CLASS and MPEX surveys are analyzed by comparing student responses with “expert opinions”. When students agree with the “expert opinion” the response is considered favorable; when students disagree with the “expert opinion,” the response is considered unfavorable.

In addition to adopting new student learning outcomes and implementing a departmental assessment plan, other changes were initiated during the 2006-2007 academic year. The number of undergraduate teaching assistants utilized in the studio courses was reduced from three to one, this was necessary to allow for sustainability as the number of studio sections increased. The department secured approval from the university to charge a laboratory course fee for both the traditional laboratory and studio courses in the fall of 2006. The first fees were collected in the spring of 2007. The funds were used to support the salaries of the undergraduate teaching assistants. Additionally, in the spring semester of 2007, university approval was gained to increase the laboratory contact hours from two to three hours per week. This allowed the studio course to be placed more easily into the weekly schedule of classes. Two models were adapted: a course meeting two hours on Monday, Wednesday, and Friday or a course meeting three hours on Tuesday and Thursday. During the summer of 2007, additional guided inquiry laboratories and supplemental instruction materials were developed for the Physics I studio course.

During the 2007-2008 academic year, additional sections of studio courses were included in the departmental schedule. The enrollment in the Physics I studio course was increased to 38 students in the fall semester and again in the spring semester to 42 students. The enrollment in the Physics II course was increased to 38 students for the year. A third faculty member began teaching studio courses this year as well. During this year, approximately 50% of our calculus-based physics courses were offered in the studio format.

In the summer of 2008, a second existing laboratory space within the department was converted into a studio classroom. Additionally, new guided inquiry laboratories and supplemental instruction materials were developed for the Physics II studio course. The following academic year, 2008-2009, 100% of the calculus-based physics courses were taught in the studio format.

Training was provided on facilitating studio courses for all faculties in the department during the summer of 2008 in preparation for the full conversion from traditional lecture and laboratory courses to introductory calculus-based studio physics courses. All trainees were provide with a Studio Physics Training notebook customized to suit the anticipated needs of the faculty teaching in the studio format for the first time. The training notebook consisted of the following materials: Select Journal Articles Focusing on Studio Physics, Sample Course Syllabi and Schedules, Newly Developed Guided Inquiry Laboratories and

Supplemental Instruction Materials, Physics Education Technology (PhET) and ActivPhysics Computer Simulation Activities, Data Studio Training Manual, and Pasco Instruction Manuals and Experiment Guides for New Computer Interfaced Laboratory Equipment. The day of training began with a short presentation on the implementation of studio physics in the department from the spring of 2006 until the present, providing new faculty with a brief motivation for the conversion from the traditional lecture and laboratory courses to the active learning studio model. Following this presentation, a powerpoint slide show was utilized to facilitate a lengthy discussion on the defining characteristics of a studio course. The following topics were discussed in great detail: integration of lecture and laboratory courses; reduction in time spent lecturing; class time devoted to active, inquiry based learning; technology enhanced learning environment; structure of collaborative group work; and high level of faculty-student interaction. The remaining time in the morning was spent training faculty to use the software for controlling the new computer interfaced laboratory equipment. In the spirit of the active learning studio model, faculty spent the afternoon working in teams investigating self-selected guided inquiry laboratories or computer simulation activities they intended to incorporate into their classes during the following semester.

During the summer of 2009, a third studio classroom was created from an existing laboratory space. This third classroom allowed for the conversion of the introductory trig-based physics courses from traditional lecture and laboratory courses into studio courses during the following fall semester, 2009. Currently, plans are being finalized to construct a fourth studio classroom from two joining lecture classrooms during the summer of 2010. The plans are to utilize this smaller studio classroom for teaching upper level courses for physics majors, such as Modern Physics, in an active learning studio model.

Results and Discussion

Results from assessment indicated the conversion from traditional lecture classes to studio classes benefited student learning. The graphs shown in Figure 2 summarize the department results of the FCI gains for Physics I courses from the spring of 2006 until the fall of 2009. During the initial pilot studio course in the spring of 2006, no significant differences were observed in average FCI gains. The traditional sections and studio section reported average gains of 0.18 and 0.17, respectively. However, in the fall semester of 2006, the average gains in the studio course increased to 0.30. The increase in the fall 2006 FCI scores may have resulted from the conversion of the existing laboratory space into a studio friendly learning environment. This was the most significant difference between the studio courses taught in the spring and fall of 2006. Slight increases in the gains for studio courses were observed in the spring of 2007 and again in the fall of 2007. The gains for the studio course decreased in the spring of 2008, yielding a value of 0.24. Decreases in FCI gains may have resulted from the addition of a third instructor teaching for the first time in the studio format. However, the gain during this semester was still greater than the gains in any of the traditional lecture sections. During the 2008/2009 academic year, operating at 100% studio courses, the gains continued to increase. A slight decrease was again detected in the fall of 2009.

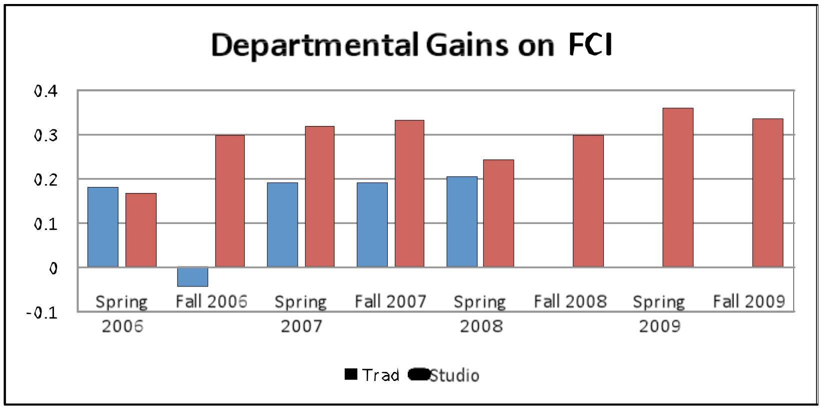

Figure 2. Departmental gains on the FCI from the spring of 2006 until the fall of 2009 are shown for both the traditional and studio Physics I courses.

The graphs displayed in Figure 3 summarize the department results of the CSEM data from Physics II courses taught from fall of 2006 until fall of 2009. The traditional lecture sections reported gains of 0.11 and 0.13 for the fall semester of 2006 and the spring semester of 2007; while the studio courses reported gains of 0.24 and 0.26, respectively. The gains in the studio sections (0.05) were lower than those in the traditional lecture sections (0.24) during the fall semester of 2007. Decreases in CSEM gains may have once again resulted from the addition of a third instructor teaching Physics II in the studio format for the first time. Recorded gains in the spring semesters are typically larger than those measured in the fall semesters. Students normally take this course for the first time in the spring semester. The largest departmental gains on the CSEM occurred during the spring semester of 2009 with a value of 0.29.

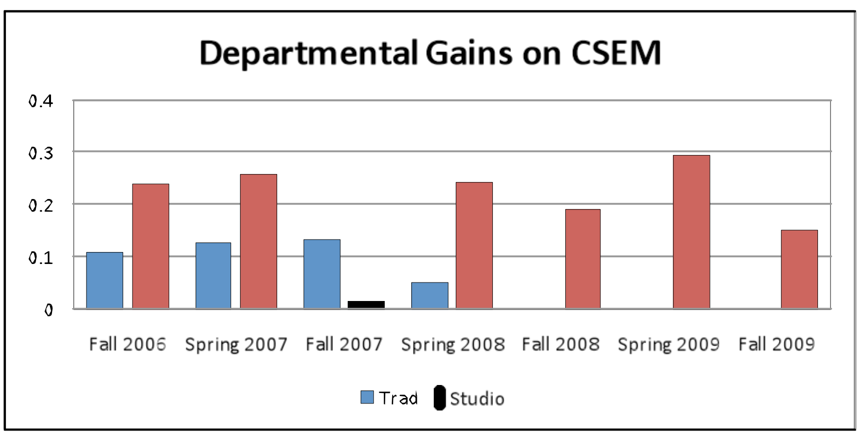

Figure 3. Departmental gains on the CSEM from the fall of 2006 until the fall of 2009 are shown for both the traditional and studio Physics II courses.

During the restructuring of our calculus-based introductory physics courses, students completed a departmental open-ended response survey from the spring semester of 2006 to the spring semester of 2007. Useful insight from the students' perspective was provided on the separate traditional lecture and laboratory experience. The following exert was taken from a student's response in the fall of 2006: "I felt the lab did not really go with the lecture. The lab went faster than the lecture so the two never matched up. So it seemed like we were learning two different parts of physics at the same time. Since the lab was always ahead of the lecture, the labs were more difficult than they were probably intended." The surveys also indicated those components of the studio format students found most favorable. One student in the fall of 2006 commented: "I liked the environment. It's relaxed and comfortable. I feel that I can ask the instructor a question without reservation. In traditional classes, asking questions seems to break the rhythm of the lecture whereas in studio physics, asking questions seems to be an integral part of the class." Another student found the integration and collaboration to be key factors in the learning environment: "The fact that we can move around and discuss what we are learning with other students. I also liked the lab integrated into lectures."

Results from the MPEX (Fig. 4), measuring shifts in Physics I students' favorable attitudes, mirrors the positive responses received from the early departmental open-ended response survey. The math link category was the only category in which students in both traditional and studio courses experienced positive shifts in favorable attitudes. The traditional students experienced a 2% larger shift in favorable attitudes than studio students. Increases in favorable attitudes in the math link category implied students in all Physics I courses felt as if they had developed an ability to use mathematical reasoning to make predictions concerning the behavior of real physical systems. Both traditional lecture and studio sections of students experience negative shifts in favorable attitudes in the effort category of -8% and -9%, respectively. These negative shifts in effort may be interpreted that students expected to make more of an effort in the course than they actually did. In the coherence category, traditional students reported positive shifts in favorable attitudes of 3% while studio students reported negative shifts of 1%. This result was unexpected. Due to the integration of the lecture and laboratory components in the studio classroom, it was expected that studio students would have seen physics as more coherent and consistent in structure than the traditional lecture students. Differences in directions of favorable attitude shifts were observed in the independence, concepts, and reality link categories. In each of these categories, studio students had positive shifts in attitudes while traditional lecture students had negative shifts in attitudes. The greatest differences in shifts were observed in the independence category, where traditional students had shifts of -1% while studio students had shifts of 7%. Since the studio environment was designed as a student-centered environment, it was encouraging to see the positive shift toward a favorable attitude in this category.

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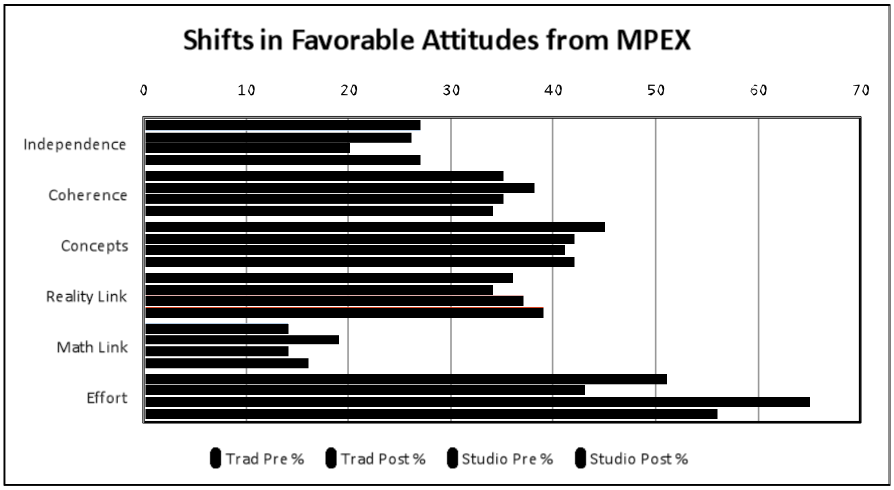

Figure 4. Pre and post percentages of favorable agreement with the expert opinion as measured by the MPEX are shown for both traditional lecture and studio Physics I courses.

Student responses from the departmental open ended survey for students who completed Physics I and Physics II courses in the two different formats were particularly informative. One of the survey questions requested this group of students compare their experiences in the traditional lecture and studio courses. In the spring of 2007, a student who had also completed Physics I in the traditional classroom and Physics II in the studio classroom shared the following experience: "In physics I we had lectures that consisted of the teacher talking the whole time. I liked this class better because the teacher talked and then we did an ActivPhysics online to see the concepts we were just lectured over."

Similarly, results from the CLASS survey on shifts in Physics II students' attitudes indicates positive shifts for the studio format in all categories measured (Figure 5). Students in the traditional lecture and studio sections of Physics II experienced positive shifts in favorable attitudes in the problem solving general, problem solving confidence, problem solving sophistication, conceptual understanding, and applied conceptual understanding categories. The positive shifts in favorable attitudes for the problem solving general category were similar with values of 6% for traditional students and 7% for studio students. The problem solving confidence category was the only category of those listed above in which studio students reported a larger positive shift in favorable attitudes with a value of 12% than their counterparts in the traditional lecture sections with shifts of 2%. In the problem solving sophistication, conceptual understanding, and applied conceptual understanding categories, traditional students averaged positive shifts in favorable attitudes of 13% compared with averaged positive shifts of 3% for students in the studio sections for these same categories. Differences in directions of favorable attitude shifts were observed in the personal interest, real world connection, and sense making/effort categories. In each of these categories, studio students had positive shifts in attitudes while traditional lecture students had negative shifts in attitudes. The greatest differences in shifts were observed in the real world connection category, where traditional students had shifts of -4% while studio students had shifts of 10%. It was encouraging to observe positive favorable shifts in the personal interest and real world connection for studio students. The literature indicates the likelihood of a student becoming a physics major correlates with their personal interest score (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Wieman, 2006).

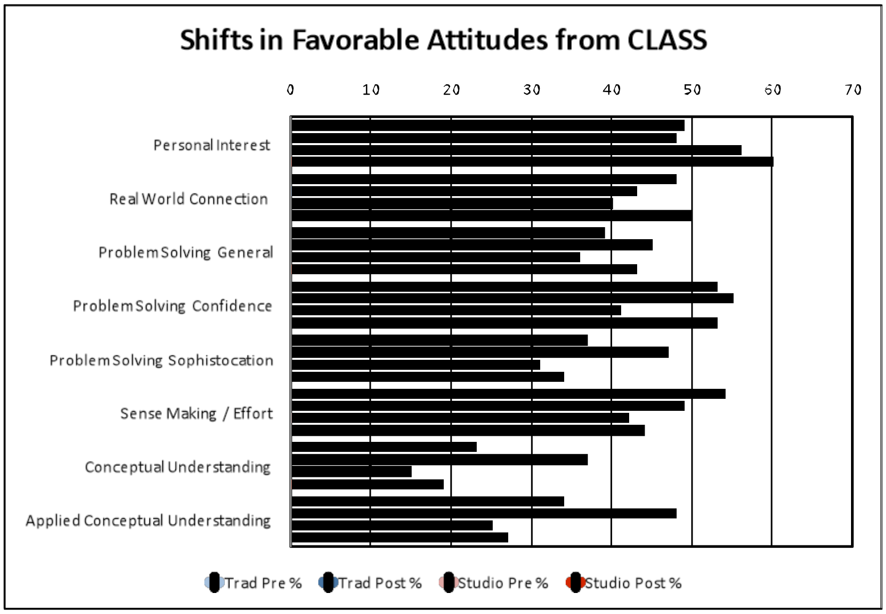

Figure 5. Pre and post percentages of favorable agreement with the expert opinion as measured by the CLASS are shown for both traditional lecture and studio Physics II courses.

Conclusions

Based on our results both the traditional format and the studio format provided positive results in student learning and attitudes. However, assessment indicated students completing the Physics I and Physics II studio courses experienced greater success in achieving the desired learning outcomes for the introductory courses. It was also evident that as we continued to modify the studio format and gained additional experience in teaching in this setting, we became more successful at having students obtain the desired outcomes. We feel students in the studio courses demonstrated a better understanding of physics concepts than their peers enrolled in the traditional lecture courses based on measured results from the FCI and CSEM conceptual exams. Shifts in students' favorable attitudes were positive for the studio format in most categories measured. While traditional methods resulted in some positive attitude shifts, as you would expect, there were several categories for both Physics I and Physics II in which students had negative shifts in favorable attitudes. It is our belief that the studio format provides a more complete learning environment in which students develop a functional understanding of physics while more effectively developing skills in problem solving, laboratory techniques, communication, and application of technologies. The positive results evident from the conversion to the studio format can best be concluded by this quote from a student who had taken Physics I in the traditional lecture format and was completing Physics II in the studio format: "In Physics I, I got a C and could barely stay awake in class. In Physics II, I have an A or really high B and have no problem staying awake in class. I feel much more confident about the concepts of Physics II then I did in Physics I."

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References

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). A new instrument for measuring student beliefs about physics and learning physics: the Colorado Learning Attitudes about Science Survey. *Physical Review Special Topics Physics Education Research* .

Dori, Y. J., Belcher, J., Bessette, M., Danzier, M., McKinney, A., & Hult, E. (2003). Technology for active learning. *Materials Today* , 44-49.

Gaffney, J. D., Richards, E., Kustus, M. B., Ding, L., & Beichner, R. J. (2008). Scaling Up Education Reform. *Journal of College Science Teaching* , 18-23.

Hestenes, D., & Halloun, I. (1995). Interpreting the Force Concept Inventory. *The Physics Teacher* , 502-506.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher* , 141-158.

Maloney, D. P., O'Kuma, T. L., Hieggelke, C. J., & VanHeuvelen, A. (2001). Surveying student's conceptual knowledge of electricity and magnetism. *American Jouranl of Physics* , 12-23.

Perkins, D. (2005). The Case for a Copperative Studio Classroom: Teaching Petrology in a Different Way. *Journal of Geoscience Education* , 101-109.

Redish, E. F., Steinberg, R. N., & Saul, J. M. (1998). Student Expectations in Introductory Physics. *American Journal of Physics* , 212-224.

Wilson, J. M. (1994). The CUPLE Physics Studio. *The Physics Teacher* , 518-523.