The introductory physics courses at the University of Alabama (UA) are, in many ways, typical of a comprehensive state university with a college of engineering. There are algebra-based (PH101/102) and calculus-based (PH105/106) courses as well as a conceptual physics course (PH115). The PH101/102 coursework is taken primarily by life-science majors and PH105/106 is taken primarily by engineering, chemistry, mathematics, and physics majors. PH101 and PH105 cover mechanics and thermodynamics. PH102 and PH106 cover electricity and magnetism and optics, but PH102 also covers modern physics. The total annual enrollment in the introductory physics courses is about 1900.

Prior to 1993 all the introductory physics courses were taught in a separate lecture-laboratory format with no separate recitation sections. Typical lecture sizes were 60-90 students. Active engagement consisted mainly of lecture demonstrations - for those faculty members who chose to do them. Problems were typically assigned but rarely
collected and graded. Laboratory sections consisted of about 20 students and were taught by a single graduate teaching assistant (GTA), with a faculty member assigned to supervise all the labs. There were minimal discussions between physics faculty and faculty in other departments whose students were served by the introductory physics courses.

In recent years, the department has made significant efforts to reform its introductory courses, most notably with the introduction of Studio Physics. This paper describes these changes and some of the lessons learned.

**Foundation Coalition**

The first significant reform efforts began in 1993 when UA became one of six institutions to be awarded a National Science Foundation - Foundation Coalition (FC) grant to improve its undergraduate engineering education curriculum (Cordes et al., 1999). The FC program was one of eight engineering coalitions funded by NSF to reform the undergraduate engineering education curriculum. Curricular improvements within the FC program centered on active and cooperative learning, teamwork, technology-enabled learning, and curriculum integration. Introductory physics, chemistry, and mathematics were included in the FC program because of their importance in the engineering curriculum. New classrooms with computer workstations for group activities were built for the program. Two pilot FC PH105/106 sections were developed with about 30 students per section. Labs were modernized to include computer data acquisition equipment. There were efforts to integrate the curriculum so that topics in the different disciplines were introduced in a more meaningful sequence, redundancy was reduced, interdisciplinary projects were assigned, and some interdisciplinary labs were developed. Common tools such as Excel, Maple, and PowerPoint were used in different courses. A goal in all courses was to minimize formal lectures and make learning more student-centered. The FC program led to extensive interactions among faculty in the different disciplines to improve the curriculum. There were also annual conferences involving FC faculty from all six participating institutions where ideas were shared.

**Studio Physics**

After the conclusion of the FC program, the UA physics department decided to implement some of the successful FC concepts in all of its introductory physics courses in a Studio Physics format beginning in 2002. The Studio format was modeled in part on the program at Rensselaer Polytechnic Institute (Cummings, et al., 1999). The Studio and FC formats are similar except that the lecture and lab are integrated in the Studio format while they were separate in the FC format. Implementing Studio Physics required new classrooms in the physics building since the FC classrooms were not available for all physics sections. Two classrooms, with capacities of 54 and 60 students, were built with support from the university and Department of Education grants. The classrooms, as shown in Figure 1, contain workstations which accommodate teams of three students. The Studio format includes three meeting days with a total of five contact hours per week (2+2+1). A GTA assists the faculty instructor during each class period and an
undergraduate Teaching Assistant (TA) (physics major) assists on the day of the week that students do a lab. By the spring of 2005, all introductory physics courses were taught in the Studio format. In 2007, however, the department began to also offer sections taught in the traditional lecture-lab format. The reasons for this change involved enrollment pressure (the largest lecture classroom can accommodate 154 students), the preference of some faculty to teach in the lecture-lab format, and the need to do comparative assessments of the two formats. Currently, the enrollment is split about evenly between the two formats.

So, what comparisons can we make between Studio and non-Studio courses? Attitudinal surveys given to students in Studio sections of PH101, PH105, and PH106 in 2002 and 2003 showed a strong preference for Studio versus non-Studio. 53% preferred Studio, 20% non-Studio, and 26% indicated no preference. A large number of these students, however, had actually not taken both Studio and non-Studio courses. Class attendance in Studio (~85%) exceeds that in non-Studio (~65%); however, this is influenced by the fact that the Studio classes typically require daily work or quizzes that are graded. Retention rates in Studio exceed those in non-studio, as shown in Figure 2. In these plots the horizontal axis is the percentage of students either withdrawing (W) or failing (F) the class and the vertical axis is the percentage of classes with W/F rates equal to or above a given W/F rate. The median rate for Studio is 16.5% while the median rate for non Studio is 23.5%.

Figure 1. Studio Physics classroom.
The Force Concept Inventory (FCI) (Hestenes, et al., 1992) has been used as pre- and post-tests to determine conceptual learning in both Studio and non-Studio PH101 and PH105. Gains vary widely and depend on the instructor. Generally, however, gains in the Studio courses are above those in the non-Studio courses. The gain is defined as

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\text{Gain} = 100\% \times \frac{\text{actual gain}}{\text{maximum possible gain}}
\]

Figure 2. W/F comparison of Studio and non-Studio formats.

Figure 3. FCI gain comparison of Studio and non-Studio formats.

100%*actual gain /maximum possible gain. Figure 3 shows cumulative plots of gains determined from 2002-2010 for the Studio and non-Studio courses. The median gains are 27% for the Studio courses and 17% for the non-Studio courses. These gains are both somewhat low compared with gains reported for interactive engagement courses at other institutions (Hake, 1998).
The apparent advantages of Studio versus non-Studio in terms of W/F rates and FCI gains could possibly be influenced by the particular instructors who teach in the different formats. While some instructors teach in both formats, most instructors – by choice – teach either the Studio or the non-Studio formats, but not both. The data for the few instructors who have taught in both formats is sparse and inconclusive in terms of the advantages of one format versus another.

The Brief Electricity and Magnetism Assessment (BEMA) test (Ding et al., 2006) has been used to determine conceptual learning in several sections of PH102 and PH106. The gains are typically lower than for the FCI and vary significantly with the instructor. The data is insufficient to determine significant differences between the Studio and non-Studio formats. Figure 4 shows combined cumulative BEMA and FCI gains for the Studio and non-Studio formats. The median BEMA gain is 20%, which is lower than the FCI gains. The department has just recently begun using the CSEM (Maloney et al., 2001) in place of the BEMA, but does not yet have much gain data.

**Conceptual Physics**

Conceptual Physics, PH115, is a course that is taken primarily by elementary education majors. Prior to 2011, the course was taught using Paul Hewitt’s *Conceptual Physics* textbook (Hewitt, 2009) and topics typically included mechanics, waves, light, electricity, and magnetism. The format of the course was similar to Studio Physics in that students did group activities and lectures were minimal. The course was well received by students; however, pre- and post-tests such as the FCI or BEMA were not given to quantify conceptual learning gains. In 2011, the course was taught by one of us (JWH) using the *Physics for Everyday Thinking* (PET) curriculum developed by Fred Goldberg and co-workers (2007). PET was designed for elementary education majors and is mostly inquiry and activity based. The concept test provided with the PET curriculum was given at the beginning and end of the course and graded using the recommended...
rubric. Pre- and post-test scores were 25% and 65% giving a normalized gain of 54%. A student opinion survey was also given at the end of the course. Nearly all students said that the hands-on activities were the best part of the course, all preferred the PET course format to the more traditional lecture-lab format, and all said they would recommend the course to other elementary education majors.

**Lessons Learned**

So, what have we learned thus far? The Studio Physics format has been used in more than one-half of the introductory physics sections since 2002. It has been well-received by students. It has the support of the university administration, the department chair, and a significant number of department faculty members. Pre- and post-concept tests have shown that Studio outperforms the non-Studio sections; however, it is not clear how much this result is affected by the particular instructors who teach these formats. Clickers have also been adopted in some of the Studio and non-Studio courses, but there is no good data yet to determine their effectiveness. The effect of course format on problem solving skills also has not been fully determined. More study is clearly needed.

Average conceptual gains in Studio (and non-Studio) courses are below expectations for interactive engagement courses. There are significant discrepancies among faculty – some consistently have high gains and some consistently have low gains. These results suggest the need for further reform of the introductory physics courses. Stronger coordination of the Studio courses is recommended. Training and mentoring of new and inexperienced faculty members is especially needed for the Studio Physics sections. Placing a new or inexperienced instructor in Studio Physics with little training can be worse than placing the instructor in a more traditional lecture course. Both graduate and undergraduate TA training needs to be improved. Labs and group activities should be revised to make them more inquiry-based and to focus more on concepts. Some of the strategies used in PET can serve as a guide in these revisions. Successful classroom practices among instructors whose students have high learning gains should be highlighted and shared more with other instructors. For example, some faculty members have achieved improved gains after requiring their students to confront conceptual questions on multiple occasions and making conceptual learning a larger part of their course grade.

As reported by Cummings (1999), the Studio Physics format does not by itself guarantee strong conceptual learning gains. Results depend strongly on the curriculum within the Studio Physics framework and how it is implemented. Low gains were obtained in the early years of Studio Physics at Rensselaer and were improved by the implementation of interactive lecture demonstrations and cooperative group problem-solving.

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