Rapid conversion of traditional introductory physics sequences to an activity-based format

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Abstract

The Department of Physics at EKU with support from the National Science Foundation's Course Curriculum and Laboratory Improvement Program has successfully converted our entire introductory physics sequence, both algebra-based and calculus-based courses, to an activity-based format where laboratory activities, problem-solving sessions and lectures are seamlessly integrated in a single classroom. We report here, the structure, staffing and materials generated for the courses and the outcomes we have observed as a result of this conversion. Our experience in making this transition can serve as a model or blueprint for other colleges and universities interested in making similar changes.

Keywords: physics, inquiry-based, studio

Introduction

For the past 20 years, there has been a growing convergence in education research and in Physics Education Research (PER), in particular, toward active learning. Active learning takes the students out of their role as passive note-takers and instructors are no longer detached explainers. Instead, the student is actively engaged in the classroom working to confront his or her misconceptions and understand difficult concepts by doing and discovering for themselves. The instructor's role is then that of a guide to the student's inquiry; presenting problems and the scaffolding necessary to reach solutions as well as checking students' results and keeping the students on a relevant and coherent path.

In this work we have taken great advantage of the remarkable work that has been done and is currently being done in PER. Using extensive experience in the classroom and tools such as the Force Concept Inventory, researchers like Arnold Arons, David Hestenes and Eric Mazur among others have shown unequivocally that in courses taught with a traditional lecture format students are quite simply not assimilating many of the fundamental concepts of physics (Arons, 1997; Halloun & Hestenes, 1985; Hestenes, Wells & Swackhamer, 1992; Hestenes & Halloun, 1995; Mazur, 1997). Further, there has been much work showing that progress can be made on understanding difficult physical concepts by making the students confront their incorrect, preconceived ideas of how physical processes occur (Hake 1994; McDermott, 1999, 1996, 2002; Laws, 1991, 1996; Hestenes, 1987, 1992, 2003; Hestenes & Halloun, 1995; Mazur, 1997). This is usually done by having the students predict the outcome of an experiment and then performing the experiment themselves and consequently building their understanding over the course of a series of simple experiments (McDermott, 1996). A more elaborate technique called "Modeling Physics Instruction," in which students develop the physical principles from laboratory experiments with only subtle guidance from the instructor has been very successful as well (Hestenes, 1987, 1992, 2003; Wells, Hestenes & Swackhamer, 1995; Halloun, 1996). Further, it has been shown that group work, carefully chosen, conceptual multiple-choice questions, and Interactive Lecture Demonstrations have been used to improve conceptual understanding (Mazur, 1997; Thornton & Sokoloff, 1990,1997, 1998, 2004; Cummings, Marx, Thornton & Kuhl 1999; Meltzer & Manivannan, 2002). Integrating these techniques for large class sizes is a difficult issue as well. However, the SCALE-UP program at North Carolina State University (NCSU) led by Robert Beichner has shown that many of these techniques can be utilized in a large classroom setting (Beichner & Saul, 2003; Beichner, Bernold, et al, 1999; Bonham, Beichner, et al, 2000.)

As can be seen, there has been a wide range of resources already generated in the field to move to an active-style classroom. We have pulled together a wide array of these different ideas into our model as well as introducing a number of novel features.

We are now running seven sections of introductory physics each semester in an activity-based format: six of the algebra-based sequence and one of the calculus-based sequence, every semester. All seven faculty members in our department have taught a section of the activity-based course. All major topics of the traditional course have been retained in the new format. We believe our transition to an activity-based format is a model that any college or university across the country can use to also make a similar conversion.

Description of Activity-Based Courses

Classrooms

During our transition, we used two classrooms we use for the activity-based course. The first was a converted standard classroom. Traditional desk-chairs were removed and replaced with 6 ft, round tables with six chairs around each table. The tables could be moved around the room and can be separated into two half tables. Additional electrical outlets were needed and were installed in the floor beneath each table. Ethernet ports were also installed around the room to facilitate internet connections. The room is enabled with a wireless signal so that is often used as well. A demonstration table was already in the room, a computer docking station was installed on the demonstration table and linked to a digital projector, which projects on a screen in the front of the room. It is important that the screen be separate from the blackboard so that they can be used concurrently.

The other classroom we used is a large traditional instructional laboratory. Outlets and Ethernet ports were already available. An instructor's docking station was installed at the front of the room with a projector and screen.

Both rooms have chalkboards at the front of the room for lecture and both have nearby "spill-over" laboratories that can be used when an activity calls for large pieces of equipment (e.g., 2.2 m dynamics tracks) and to separate students for tests.

In the spring semester of 2012, we moved into a new science building with four classrooms designed especially for our activity-based courses (See Figure 1). Facilities do make a significant difference in the ease of transforming to an activity-based format. The arrangement we used during our transition period was less than ideal, but is an example of how creative use of existing space can be utilized.

Class-size and Staffing

We offer seven sections of introductory physics sequences each semester with 35-40 students in each section. This serves about 250 students per semester. Class size is limited by both the classroom size and our ability to work with students effectively. The new science building allows us to accommodate

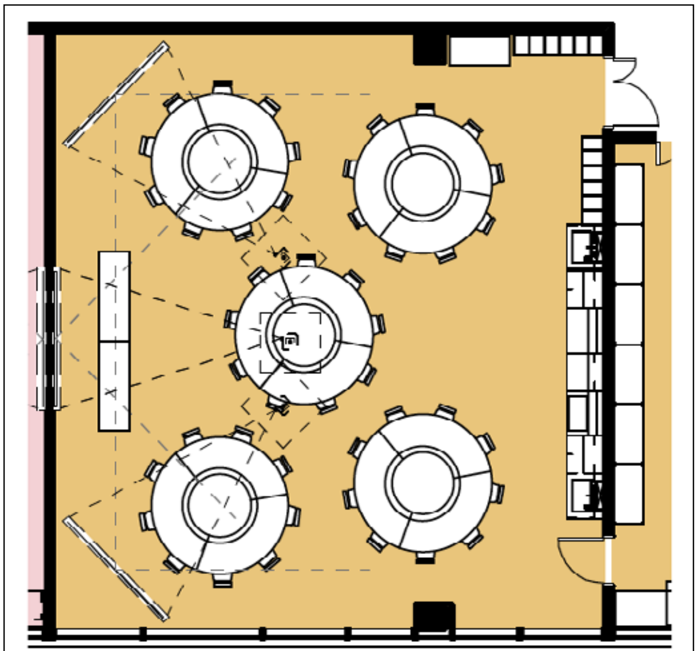

Figure 1: Schematic diagram of classrooms in our new science building designed for integrated lecture/laboratory courses

45 students in each section, but class size is capped at 40 with overrides allowed with consent of the instructor. These limitations are supported by our administration.

Classes meet for six hours a week, usually for two hour sessions every Monday, Wednesday and Friday, but we have tried three-hour classes on Tuesday and Thursday as well. Students receive five hours of college credit for completing the course, instructors receive six hours (two courses) of teaching credit. Each section is also assigned a secondary instructor who receives two hours of teaching credit. The primary instructor is responsible for organizing the course, creating the syllabus, decisions on class time activities and most, if not all, of the lecturing. The secondary instructor helps out in class with the activities and problem-solving sessions and does grading associated with the hands-on activities. Both instructors will normally be in the classroom during the class periods. The laboratory activities and problem-solving sessions are much more effective, reducing students' down-time waiting for assistance, with two instructors in the room.

Additionally, undergraduate physics majors, usually juniors and seniors, are assigned to the classroom as teaching assistants. Occasionally an experienced instructor will have undergraduate TA's in place of a secondary instructor. Involving our undergraduates in teaching the courses has been an outstanding success, a result of the project we did not anticipate, as we will discuss later.

Note that for 100 students, we would need about three sections of activity-based classes, which would be about 24 hours of instructional credit. In the traditional format, this would be three lecture sections and four laboratory sections. The three lectures would have been four hours of teaching credit each and the laboratory sections would be 2.25 hours (three-quarters of the three contact-hour lab) of instructional credit each for a total of 21 hours. So the cost of staffing the activity-based courses is not overwhelmingly more than the traditional courses. Occasionally, as well, an experienced instructor can teach the course with help from just one or two competent undergraduates. This has been especially true in the second semester calculus-based physics where the students are more able to perform self-directed work and class sizes are somewhat smaller.

As discussed below, instructors who are assigned to an activity-based section of introductory physics must first serve as a secondary instructor to get the experience needed to be effective in our classrooms. This has provided us with a way to train new personnel in our approach. Most faculty, even the experienced ones, show some trepidation at teaching in the new format the first time. However, after trying the new hands-on approach, all have become enthusiastic supporters of the new approach we are using.

Course Content

We have divided the material for each course up into four or five units depending on the course with some shorter optional units that can be used at the instructor's discretion. Most of the time, instructors do not have enough class-time for more than one of the optional units. The units we have developed are listed on Table 1.

Often times the calculus-based units cover the topic with more depth. For example, in the Electric Circuits unit in the algebra-based course discussion of AC circuits is omitted, but it is included in the calculus-based course.

Most of the content from a traditional course is preserved in the new format, especially in the calculus-based sequence, and all of the core ideas of basic physics are kept in both sequences. Discussions of waves, thermodynamics/physical chemistry and modern physics are very difficult to find time for in the new format.

First Semester Calculus-based Course (PHY 201)		First Semester Algebra-based Course (PHY 131)	
Unit	**Topic**	**Unit**	**Topic**
I	Motion and Kinematics	I	Motion and Kinematics
II	Newton's Laws of Motion	II	Newton's laws and Forces in One-Dimension
III	Energy and Momentum	III	Newton's laws and Forces in Two-Dimensions
IV	Rotations and Revolutions	IV	Energy and Momentum
V	Gravitation	V	Rotations and Revolutions
VI	Simple Harmonic Motion	VI	Waves and Interference *(optional)*
VII	Pressure, Density and Bouyant Force *(optional)*	VII	Pressure, Density and Bouyant Force *(optional)*
VIII	Calorimetry *(optional)*	VIII	Simple Harmonic Motion *(optional)*
		IX	Calorimetry *(optional)*
Second Semester Calculus-based Course (PHY 202) Topics		**Second Semester Algebra-based Course (PHY 132) Topics**	
Unit	**Topic**	**Unit**	**Topic**
I	Electrostatics	I	Electrostatics
II	Electric Circuits	II	Electric Circuits
III	Electromagnetism	III	Electromagnetism
IV	Waves and Interference	IV	Geometric Optics
V	Geometric Optics	V	Wave Optics *(optional)*
VI	Wave Optics	VI	Radioactivity *(optional)*
VII	Radioactivity *(optional)*		

Table 1: Topics Taught in Activity-Based Courses

Description of Activities

We have developed a wide range of different types of activities. Many are laboratory-style activities, some are interactive lecture demonstrations, some are pencil-and-paper exercises that lead students in developing a mathematical concept, and some are straight-forward problem-solving activities.

We have linked all of these types of activities with a common structure that we call *Forced Response*, where the students are required to answer a question at the beginning of the activity *(initial response*), so that they demonstrate, to the instructor and to themselves, what misconceptions they have about the subject as they first approach the material. At set points throughout the activity there are stopping points where students reflect on what they just did (*final response*) much like McDermott's "checks" (McDermott, 1996). Having the students commit to an initial response question has been shown to be important when doing ILDs by Thornton and Sokoloff (1990; 1997; 1998).

For each unit there is a set of activities that instructors can move through, spending some time between activities giving short lectures, working a small number of problems for the students, and giving students time in class (when they have help) to work on homework assignments. The development of these activities is continuous and every faculty member is expected to contribute to the evaluation and improvement of the activities.

Use of Technology

We have made a conscious effort in making this transition to take advantage of the newest instructional technology. We use a combination of *Vernier* and *PASCO* equipment, but we use predominately the *Vernier* system of collecting data on computers, and note that the *PASCO* equipment and software is excellent as well. We have purchased portable laptop computers for students to take to their experiments and use the *LoggerPro* computer software to collect and analyze data. These systems allow students to see the data as it is being collected and gives them a better sense of how a graph represents the phenomena they are seeing directly. Instructors can also immediately see any problems in the experiments and can use probing questions to steer students to the correct path.

We use the same data collection systems for several of our interactive lecture demonstrations. Students can predict the outcome of an experiment and then immediately see what actually occurs which allows them to confront their misconceptions. In addition to the ILDs of Sokoloff and Thornton (2004), we have developed three of our own ILDs along with simple demonstration equipment to illustrate basic physics concepts. They are the Force Board, the Torque Board and the Circular Motion Board and descriptions of them have been published recently (Yoder & Cook, 2010.)

All of our introductory physics classes use the *MasteringPhysics (MP)* online homework system, a product of Pearson Education Publishing. This has changed the nature of our classrooms as students now learn concepts in class and the self-directed, instant feedback associated with MP serve to reinforce topics developed in class.

We have also begun using *iClicker,* a clicker system that allows us to use, for example, Mazur's (1997) *ConcepTests* more easily and give students immediate feedback on their understanding of the physics.

Description of Transition Process

Facilities

To begin the process we adjusted some of our rooms to facilitate the new activity-based format. Most of this has been discussed above when describing the rooms we use for the courses. Some new laboratory equipment was also needed. We used mostly *Vernier* equipment with some *PASCO* equipment as well. The *PASCO* dynamics track system is a staple of our units on mechanical systems.

We also purchased 18 laptop computers to use with the activities. A grant from NSF helped with this expense. These computers are used by students to take data with the *Vernier* data loggers and to access *Mastering Physics* assignments in class. Laptops are especially usefully because of their portability and wireless internet connection in the classrooms allows students to use these computers to work in small groups anywhere in our classrooms. Our students have begun to bring their own netbooks to class and *Vernier* licensing allows the software to be loaded on their computers as well.

Getting proper facilities and equipment is an important first step in making the transition, but most physics departments at most higher education institutions will have rooms and equipment that can be modified to suit the needs of the activity-based class. This should not be an insurmountable barrier. A supportive administration provided funds to purchase the round tables used in our classrooms. This support is vital in making a transition such as we have done.

Timeline

The transition to the new format did not happen overnight, but was done over the course of about two years. We felt that everyone who would teach the course should first serve as a secondary instructor for an activity-based section to get a sense of what the course is about and what the teaching method looks like. Dr. Jerry Cook had used McDermott's (1996) *Physics by Inquiry* to develop a course designed for middle school teachers and had been teaching that course for a number of years. He was well-versed in the activity-based approach and so taught the pilot section of the calculus-based course. Dr. Garett Yoder had sat in on Dr. Cook's Physics by Inquiry course and then taught the inquiry course for teachers several times. With that background, Dr. Yoder taught the first section of the algebra-based course. Mr. David Taylor, a retired high school physics teacher also had much experience using activity-based format, in particular the Modeling Physics approach developed by Hestenes (Hestenes, 1987, 1992, 2003; Hestenes & Halloun, 1995.) The progression to more and more activity-based sections with different instructors is shown in the Table 2.

In the fall of Academic Year 1 (AY1) we taught our first activity-based section of the calculus-based course, PHY 201. Two years later, in the fall semester, our entire set of courses in the introductory physics sequences was being offered in the new format.

This type of transition would not have been possible without this faculty buy-in, which was fostered by several approaches we took in structuring the course and staffing. Faculty were, in general, nervous about taking on the new format, but with many of the materials for the course already created and the opportunity to serve as a secondary instructor in an activity-based section before they had full responsibility for a course was very helpful in alleviating this anxiety. Further, faculty in multi-section courses meet in small groups weekly to discuss activities and new materials, and to coordinate their activities and presentations. Overall, faculty have been very receptive to the new format, have found it a refreshing and powerful instructional method and have found ways to improve the course after teaching the course for the first time.

INSERT TABLE 2 HERE

Outcomes

Quantitative Outcomes

We have two basic quantitative outcomes that we use for assessment or evaluation of the courses. The first is the Force Concept Inventory (FCI) exam that has become widely accepted for almost two decades in Physics Education Research for evaluating conceptual understanding of basic Newtonian mechanics. The FCI was only used for the first semester courses (PHY 201 and PHY 131) where Newton's laws are specifically addressed.

Academic Year and Semester of Transition	Activity-Based Sections	Lead Instructor	Secondary Instructor
AY1- Fall (2007)	Pilot Section of PHY 201	Dr. Jerry Cook	Dr. Jennie Campbell
AY1- Spring (2008)	Pilot section of PHY 202	Dr. Jerry Cook	(none)
	Pilot section of PHY 131	Dr. Garett Yoder	(none)
AY1-Summer (2008)	Pilot section of PHY 132	Dr. Garett Yoder	Dr. Jessica Lair
AY2- Fall (2008)	PHY 201	Dr. Jerry Cook	Dr. Jessica Lair
	PHY 131	Mr. David Taylor	Mr. Monte Farmer
	PHY 132	Dr. Garett Yoder	Mr. Matt Lykins
AY2-Spring (2009)	PHY 202	Dr. Jerry Cook	Dr. Marco Ciocca
	All sections (3) of PHY 131	Dr. Garett Yoder	Mr. Matt Lykins
		Dr. Jessica Lair	Dr. Xiunu Lin
		Mr. David Taylor	Mr. Monte Farmer
	PHY 132	Mr. David Taylor	Mr. Monte Farmer
AY2-Summer (2009)	PHY 131	Dr. Jessica Lair	Mr. Monte Farmer
	PHY 132	Dr. Garett Yoder	Mr. Zach Miller
AY3 – Fall (2009)	PHY201	Dr. Jerry Cook	Mr. David Taylor
	All sections (5) of PHY 131	Dr. Jessica Lair	Dr. Jing Wang
		Dr. Marco Ciocca	Mr. Matt Lykins
		Mr. David Taylor	Mr. Monte Farmer
		Dr. Xiunu Lin	Mr. Monte Farmer
		Mr. Matt Lykins	Mr. Brent Marcum
	PHY 132	Dr. Garett Yoder	Dr. Farzaneh Ebrahimi-Fakhari

Table 2: Timeline of courses taught in activity-based format.

The other measured outcome is that of student success: What percentage of students finished the course, the percentage that earned an A, B or C and finished the course and the class GPAs.

Calculus-based Physics (PHY 201):

FCI data for Physics 201 for four preceding semesters is presented in Table 3. In this table fall 2005 and fall 2006 sections are traditional physics courses and fall 2007, fall 2008, fall 2009 and fall 2010 are taught in the new activity-based format. Fall 2006 was a transitional course in that many of the new activities were being phased into that course as a test of how they would work and their effectiveness. Many of these activities are based on the materials supplied by *Vernier*, which we have found to be excellent. The FCI was given to the class at the beginning of the course and again at the end of the course. The fourth column in Table 3 gives us the FCI average on the pre-test for the class and fifth column gives the FCI average on the post-test. The last column gives the normalized gain (Hake, 1998.) Gain (g) is calculated by:

$$g = \frac{post - pre}{30 - pre}.$$

30 is the best possible score on the FCI.

There is a noted difference between the only truly traditional course (fall 2005) and the other four semesters with the exception of fall 2010 in which the FCI gain was only 0.27 as compared to gains of over 0.30 for other semesters in which the new format we used. We are currently looking at the data from that course. Some possible causes of what we consider a significant drop in FCI gain may be the new, expanded audience that we have attracted from other majors such as fire science and forensics. Another factor may be that these students simply are not taking the post exam serious enough, and in fall 2011 we will assign some small credit to the student FCI gain to get the students' attention. The gain improved from 0.28 to an average of 0.34 in the other three semesters considered activity-based. Even in fall 2010 selective observations of gain for motivated students show individual gains of as high as 0.7. We still feel confident that our new approach is working, but that our evaluation, especially in the calculus-based course, needs to be better structured, such as the case in the algebra-based courses. It should be noted that a mix-up between instructors prevented collection of FCI data in fall 2009.

Table 4 shows our outcomes in student success. Our measures of student success include: percentage of students completing the course, percentage of students *successfully* completing the course (that is, earning an A, B or C in the course), student rating of instruction and class GPA. Of particular interest is the increase in students who have successfully completed the course, (in the sixth column) divided by the number of students who started the course (in the fourth column.) This number has consistently gone up and is an indicator that students are finding the new format more conducive to learning. This course was taught in all semesters by the same instructor who gave an identical final exam to all sections. Students are finding the new format accessible as is supported by the low withdrawal (W) rate. Hardly any students withdraw from the calculus-based course. They are instead realizing that they have the opportunity to succeed in the course.

The GPA for each section is given in the last column and the students satisfaction in the course as measured by the rating of students on a 5-point scale on the response item: "Overall I rate this course as excellent" with 5= Definitely True, 1= Definitely False. This question is from the student ratings of instruction developed by the Individual Development and Education Assessment (IDEA) Center at Kansas State University.

Semester	Instructor	Course Type	Pre-test Ave.	Post-test Ave.	Gain
Fall 05	7	Traditional	10.5	16	0.28
Fall 06	7	Hybrid	11.2	18	0.36
Fall 07	**7**	**Activity-based**	**13**	**18.4**	**0.32**
Fall 08	**7**	**Activity-based**	**12.3**	**18**	**0.32**
Fall 09	**7**	**Activity-based**	**N/A**	**N/A**	**N/A**
Fall 10	**7**	**Activity-based**	**11.3**	**16.3**	**0.27**

Table 3: FCI Results for Calculus-based Introductory Physics (PHY 201)

Algebra-based Physics (PHY 131):

The FCI results for our algebra-based course (PHY 131) are given in Table 5. Here we see more marked improvement in FCI results across the board. This improvement seems to be independent of instructor and shows that the new format is improving conceptual learning. The traditional courses were taught before the spring 2008 semester, which is when the first activity-based section of PHY 131 was taught. The comparison of FCI gain before and after that course shows a marked improvement in gain. The fact this gain is across the board and con-

Semester	Instructor Code	Course Type	Students started	Students finished	Students with A, B or C	Course satisfaction (IDEA)	% Students finished	% of ABC students	% ABC students of students finished	Class GPA
Fall 05	7	Traditional	45	31	20	4.1	68.9	44.4	65	2.03
Fall 06	7	Traditional	26	23	16	4.4	88.5	61.5	70	2.39
Fall 07	**7**	**Activity-based**	**29**	**27**	**22**	**4.2**	**93.1**	**75.9**	**81**	**2.74**
Fall 08	**7**	**Activity based**	**31**	**25**	**22**	**3.9**	**80.6**	**71.0**	**88**	**2.52**
Fall 09	**7**	**Activity-based**	**43**	**41**	**28**	**4.1**	**95.3**	**65.1**	**68**	**2.36**
Fall 10	**7**	**Activity-based**	**39**	**38**	**30**	**3.8**	**97.4**	**76.9**	**80**	**2.44**

Table 4: Student Success in Calculus-based Introductory Physics (PHY 201)

Semester	Instructor	Course Type	Pre-test Ave.	Post-test Ave.	Gain
Fall 07	2	Traditional	9	11.3	0.11
Fall 07	3	Traditional	9	10.3	0.06
Fall 07	4	Traditional	9.2	12.1	0.14
Fall 07	5	Traditional	7.9	11.3	0.15
Spring 08	1	Traditional	9	11.5	0.12
Spring 08	4	Traditional	8.7	10.7	0.09
Spring 08	**6**	**Activity-based**	**10.1**	**15**	**0.25**
Fall 08	8	Traditional	8.1	13	0.22
Fall 08	**9**	**Activity-based**	**7.85**	**18.6**	**0.49**
Fall 08	9	Hybrid	10.2	19.4	0.46
Fall 08	8	Hybrid	9.56	16.1	0.32
Spring 09	**9**	**Activity-based**	**8.97**	**14.7**	**0.27**
Spring 09	**1**	**Activity-based**	**7.76**	**12.1**	**0.20**
Spring 09	**6**	**Activity-based**	**8.88**	**16.1**	**0.34**
Summer 09	**1**	**Activity-based**	**8.56**	**13.2**	**0.22**
Fall 09	**2**	**Activity-based**	**9.1**	**14.71**	**0.27**
Fall 09	**1**	**Activity-based**	**6.88**	**11.875**	**0.22**
Fall 09	**10**	**Activity-based**	**10.04**	**11.81**	**0.09**
Fall 09	**9**	**Activity-based**	**10.19**	**14.88**	**0.24**
Fall 09	**11**	**Activity-based**	**8.76**	**11.89**	**0.15**
Spring 10	**12**	**Activity-based**	**10.14**	**13.95**	**0.19**
Spring 10	**10**	**Activity based**	**9.47**	**13.45**	**0.19**
Spring 10	**2**	**Activity-based**	**8.47**	**14.88**	**0.30**
Fall 10	**13**	**Activity-based**	**11.04**	**17.1**	**0.32**
Fall 10	**12**	**Activity-based**	**8**	**13.75**	**0.26**
Fall 10	**2**	**Activity-based**	**10.48**	**19.48**	**0.46**
Fall 10	**1**	**Activity-based**	**9.48**	**12.13**	**0.13**
Fall 10	**14**	**Activity-based**	**10.77**	**16.08**	**0.28**
Spring 11	**6**	**Activity-based**	**8.97**	**17.88**	**0.42**
Spring 11	**10**	**Activity-based**	**7.94**	**15.36**	**0.34**
Spring 11	**15**	**Activity-based**	**7.72**	**16.40**	**0.39**

Table 5: FCI Results for Algebra-based Introductory Physics (PHY 131)

tinuous is verification of our efforts.

The student success data (Table 6) is less informative as they show great variety across the board and is strongly instructor-dependent. The FCI gain is not.

We believe our data indicate that our new activity-based course is better than the old version based on a more traditional lecture mode. Student satisfaction and the numbers of students taking our courses is further indication of the success of our new introductory physics sequence.

FCI scores did not initially see any improvement from the traditional course to the activity-based course. However, in the recent fall 2010 and spring 2011 semesters we have seen a remarkable, almost across-the-board uptick in FCI scores with gains in the 30 percent range with a high of 46 percent in a single section in fall 2010 and scores for all sections more than 30 percent in the following spring. In fall 2010, we had given the FCI as an online test, where students saw questions one-at-a-time, could not return to previous questions and did not find out if they got a particular question correct. However, when we saw the high scores, we still felt that perhaps students had found a way to beat the system to improve their score. The following semester we went back to giving the paper test on a standard, multiple-choice answer sheet. The scores remained quite high. We now believe this is a real result and we will continue to monitor this in future semesters. The gain in FCI scores was not immediate and we think this is a result of having new instructors becoming more comfortable in the new format and taking better advantage of activity-based style. Other factors that could help account for this improvement are that we increased the mathematics prerequisite for the course to include trigonometry and we also started to use the *iClicker* system to help deliver some of the material. Neither of these seems to be enough to account for the kind of gain we are now seeing, but may be a result of all of these factors. We expect to report on updated data in a future article.

A further advantage of the new format allows us to much more easily incorporate advances in Physics Education Research. If we want to move to a more heavily inquiry or modeling approach, the new format supports that. If we want to use recently developed lecture demonstrations, clickers, *ConcepTests* or lecture tutorials, the new format supports those approaches as well. Our faculty will be able to explore many of these new state-of-the-art instructional techniques in these activity-based classes to further improve our quantitative results. This flexibility toward different teaching approaches may be the biggest advantage of the new format.

INSERT TABLE 6 HERE

Non-quantitative outcomes

There are several less quantitative outcomes of this transition that we think

Semester	Instructor Code	Course Type	Students started	Students finished	Students with A, B or C	Course satisfaction (IDEA)	% Students finished	% of ABC students	% ABC students of students who finished	Class GPA
Fall 07	2	Traditional	39	31	23	3	79.5	59.0	74.2	2.45
Fall 07	3	Traditional	31	24	18	4.5	77.4	58.1	75.0	2.54
Fall 07	4	Traditional	40	37	28	3.7	92.5	70.0	75.7	2.41
Fall 07	5	Traditional	40	32	19	3.9	80.0	47.5	59.4	2.00
Spring 08	1	Traditional	40	37	29	3.5	92.5	72.5	78.4	2.24
Spring 08	4	Traditional	43	39	34	3.8	90.7	79.1	87.2	2.95
Spring 08	**6**	**Activity-based**	**40**	**34**	**16**	**3.3**	**85.0**	**40.0**	**47.1**	**1.71**
Summer 08	3	Traditional	40	35	24	N/A	87.5	60.0	68.6	2.26
Fall 08	8	Traditional	34	27	19	3	79.4	55.9	70.4	2.83
Fall 08	**9**	**Activity-based**	**41**	**40**	**33**	**4**	**97.6**	**80.5**	**82.5**	**2.69**
Fall 08	9	Traditional	30	29	26	4.3	96.7	86.7	89.7	1.59
Fall 08	8	Traditional	36	27	19	2.1	75.0	52.8	70.4	2.97
Spring 09	**9**	**Activity-based**	**37**	**36**	**33**	**3.5**	**97.3**	**89.2**	**91.7**	**2.24**
Spring 09	**1**	**Activity-based**	**33**	**29**	**19**	**3.7**	**87.9**	**57.6**	**65.5**	**1.87**
Spring 09	**6**	**Activity-based**	**36**	**30**	**16**	**3.8**	**83.3**	**44.4**	**53.3**	**2.81**
Summer 09	**1**	**Activity-based**	**29**	**27**	**22**	**N/A**	**93.1**	**75.9**	**81.5**	**2.09**
Fall 09	**2**	**Activity-based**	**37**	**35**	**32**	**2.4**	**94.6**	**86.5**	**91.4**	**3.12**
Fall 09	**1**	**Activity-based**	**34**	**33**	**27**	**3.3**	**97.1**	**79.4**	**81.8**	**2.87**
Fall 09	**10**	**Activity-based**	**42**	**34**	**20**	**3.2**	**81.0**	**47.6**	**58.8**	**2.23**
Fall 09	**9**	**Activity-based**	**35**	**31**	**22**	**3.3**	**88.6**	**62.9**	**71.0**	**2.4**
Fall 09	**11**	**Activity-based**	**29**	**25**	**16**	**2.7**	**86.2**	**55.2**	**64.0**	**2.33**
Spring 10	**12**	**Activity-based**	**35**	**32**	**21**	**3.8**	**91.4**	**60.0**	**65.6**	**2.68**
Spring 10	**10**	**Activity-based**	**37**	**34**	**25**	**3**	**91.9**	**67.6**	**73.5**	**2.32**
Spring 10	**2**	**Activity-based**	**42**	**33**	**21**	**3.4**	**78.6**	**50.0**	**63.6**	**2.66**
Fall 10	**13**	**Activity-based**	**37**	**34**	**25**	**3.2**	**91.9**	**67.6**	**73.5**	**2.26**
Fall 10	**12**	**Activity-based**	**36**	**32**	**23**	**3.5**	**88.9**	**63.9**	**71.9**	**2.4**
Fall 10	**2**	**Activity-based**	**36**	**31**	**24**	**3.8**	**86.1**	**66.7**	**77.4**	**2.48**
Fall 10	**1**	**Activity-based**	**36**	**33**	**30**	**3.4**	**91.7**	**83.3**	**90.9**	**3.18**
Fall 10	**14**	**Activity-based**	**28**	**24**	**15**	**3.6**	**85.7**	**53.6**	**62.5**	**2.04**

Table 6: Student Success in Algebra-based Introductory Physics (PHY 131)

are very important. The first is that our enrollments in both calculus-based and algebra-based introductory physics has increased dramatically. We currently have record enrollments in both courses. We attribute this to the new more student friendly manner of instruction and learning that we are using.

Secondly, out of the necessity of managing a classroom of 40 students, we had assigned physics majors to assist the instructor, helping run laboratory activities and work with students on problem-solving activities in both the calculus-based sections and the algebra-based section. These students had been through the activity-based courses (PHY 201 and PHY 202) so they knew what to expect in terms of the format of the courses. Since we used the calculus-based sections as pilot classes, from the beginning we had physics majors available to help in the algebra-based sections. This initiative to utilize undergraduates has been invaluable to instructors, students, physics majors and to the project as a whole. Not only is the class more likely to stay on schedule with all groups getting the competent guidance they need, the students in the class are often more comfortable asking other students for help and guidance than they are asking the professor who controls their grade. It is a great experience for the physics majors as well. By teaching the material, they learn the physics at a more robust level and also develop teaching and communication techniques, which will serve them well regardless of what they choose to do after graduation. Many of these same upperclassmen also work in our physics tutoring lab. Having a familiar face in the tutoring lab is very inviting for students in the introductory courses. The use of the tutoring lab by students has increased dramatically since we starting teaching in this new format.

Finally, our upper division enrollment has increased dramatically. For example, in Physics 375, thermodynamics, we have seen a 300 percent gain in enrollment. This is true across the board in our advanced physics courses. The only variable that we can identify as having been changed from previous years has been the transition to our new course framework. Students are identifying with our approach and are choosing physics as a career. This is a result we never envisioned, but is pleasing to both the department and the upper administration.

A Model for Other Universities

Although every higher education institution is different, we think our model of transition can be implemented at many, many different types of institutions. The key is faculty and administrative buy-in. We have shown that we can address all of the principle topics in a standard introductory physics class without substantially increasing the teaching load. Larger institutions that have large class-sizes also often have graduate students employed as teaching assistants in laboratory and recitation sections. These GTA under a faculty member that coordinates a number of sections could achieve the same kind of situation that we have in our department.

Facilities are fairly simple to arrange (but are important). A standard laboratory room or classroom can be rearranged to accommodate tables that serve for holding laboratory equipment as well as facilitating group work.

Pilot sections of courses can be used, as we did, to get people involved and have them understand how the course works and what the course is about. There are workshops around the country that work with instructors to develop inquiry-style teaching strategies. We found that, once they started, faculty were eager to try the new approach.

Materials for classwork are also widely available. We've relied heavily on Physics with Computers from Vernier, Physics by Inquiry by McDermott (1996) and Modeling Physics by Hestenes (1987, 1992, 2003) as well as developing our own activities, which we can make available (Wells, Hestenes & Swackhamer,1995). There are also materials available from the SCALE-UP group with Beichner and Interactive Lecture Demonstrations from Laws, Thornton and Sokoloff (Beichner & Saul, 2003; Beichner, Bernold, et al, 1999; Bonham, Beichner, et al, 2000; Thornton & Sokoloff, 1990,1997, 1998, 2004; Cummings, Marx, Thornton & Kuhl 1999; Meltzer & Manivannan, 2002).

Future Work

We have two specific ideas for future work along these lines. The first is to apply this approach to our lab-based introductory astronomy course. This is a 100-level course designed for students across campus, using very little mathematics. We think moving this course to activity-based format will increase our student success considerably. Student evaluations (IDEA scores) for these courses are always fairly low, as students find out that astronomy is more than memorizing the names of the planets. A more unified approach, keeping the laboratory activities tied to the lecture material, could be a substantial improvement in the course. We have a set of lab activities that can be modified for an inquiry-style course, we have the sky simulation program *Starry Night* and sets of activities have been written to guide students around the sky with this program, there are lecture tutorials that have been developed for introductory astronomy and other materials for the laboratory (Desch & Terndrup, 2010). So the resources are there to develop this new course.

The other idea is dissemination of the materials and philosophy of approach to schools in our region and state to have more students, especially students who are likely to transfer to Eastern Kentucky University, exposed to this style of learning and gain better understanding and a more positive impression of physics and of science more generally.

Conclusion

The Department of Physics and Astronomy at Eastern Kentucky University has successfully integrated the laboratory and lecture components of their introductory courses into a seamless whole. We have done this while keeping all major standard topics in the courses with very little increase in teaching load for the department. We have measured a positive influence in making this transition on FCI scores, student success and student's attitude toward science and toward physics and expect those indicators only to improve. The activity-based format will also allow us to incorporate many different types of advances in education research without disrupting the classroom. We recommend our transition as a model for other institutions of higher education to transform their classrooms as well to this powerful, flexible design.

Acknowledgements

This work was done with the support of the National Science Foundation (NSF) Course, Curriculum and Laboratory Improvement (CCLI) Phase I program. (Grant #0633126)

The authors would also like to thank Mr. David Taylor, whose experience using activity-based Modeling Physics Techniques was crucial to the success of this project.

We also want to acknowledge the faculty of the department of Physics and Astronomy: Dr Jessica Lair, Dr. Marco Ciocca, Dr. Xiunu Lin and Dr. Jing Wang as well as Mr. Monte Farmer and Dr. Matt Lykins for the past and on-going willingness to embrace the activity-based format and find ways to make it work.

Thanks also to Dr. Mark Biermann who lent the project administrative support to get the transition process up and running.

Finally, we need to thank the undergraduates who showed such willingness to help and make the classroom activities function smoothly: Barry Farmer, Chad Terrell, Zachariah Miller, Jimmy Hendrickson, Justin Adkins, John Franklin, Joseph Ramsey, Joseph Snyder, George Anderson, Alex Henegar, Chris Rosenbaum and Jennifer Powell.

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