Scaling Up Arizona State University's First-Year Integrated Program in Engineering: Problems and Solutions

Sarah Duerden, Bruce Doak, Jeanne Garland, Meredith Green
Ron Roedel, Pete Williams, Joan McCarter & D. L. Evans
Arizona State University, Tempe, AZ 85287

Abstract

This paper discusses how scale-up from a pilot of 32 students to 80 students affected the integrated delivery of material in English composition, physics, and engineering to a cohort of freshman engineering students. It also discusses how collaborative learning and projects were structured to fit 80 students, the effects of class size on student-to-student interaction and student-to-faculty interactions in and out of the classroom, and what modifications were made to the classroom facilities to accommodate these projects. Although there were some detrimental effects accruing to the scale-up, for the most part, student performance was unaffected or slightly improved.

Introduction

The Freshman Integrated Program in Engineering (FIPE) at Arizona State University, a *Foundation Coalition* sponsored program, integrates a 15 hour block of engineering, calculus, physics and English in the first semester and replaces engineering with chemistry in the second semester of the freshman year. The *Foundation Coalition* [1] is attempting the systematic reform of undergraduate engineering education using four main thrusts (active learning, technology infusion, curriculum integration, and assessment and evaluation) to develop a desired set of student outcomes [2]. The FIPE program, while integrating subject matter, still identifies individual courses on a student's transcript and uses instructors from traditional departments to deliver the bulk of the material usually taught to freshmen. The instructors work together to make their course material complementary to that from the other disciplines and to integrate the involved disciplines as seamlessly as possible[3]. Such integration, although much less than making one large 15 hour package without disciplinary distinctions, still involves a non-trivial learning curve for instructors. Therefore, an initial 32-student pilot allowed the instructors to begin negotiating this learning curve. The program began with a 32-student pilot program in which 31 students were actually enrolled. The faculty team knew that ASU could not "institutionalize" a 32 student-size class at the freshman level, but they chose to "experiment and learn" at this size due to several factors, not the least of which was that a physical facility was available that could accommodate the small scale experiment. The third iteration increased to 80 students with 77 actually enrolled. This intentional increase in enrollment presented some interesting problems that required creative solutions.

The Problem

The first problem involved determining the extent of the scale-up (e.g., how large was large enough?). This was complicated by the fact that freshman composition is normally taught to section sizes of 25 students or less, calculus to section sizes of 45 students or less, physics and chemistry to lecture section sizes of up to about 250 students (with smaller recitations and laboratory sections), and the beginning freshman engineering course to section sizes up to 125 students (with a smaller recitation section). Meetings with all of the department chairs involved in the program led to the decision that a target of 80 students would be appropriate for the fall semester of 1996. English, therefore, agreed to assign three instructors to the section. Mathematics agreed to assign either two instructors or one instructor and one teaching assistant (who might normally be assigned his or her own normal-size section of calculus). Similarly, physics agreed to assign one faculty and one or more teaching assistants. Engineering would allow up to two instructors to be assigned.

The second problem was delivering the course material and projects that were used in the pilot program with 32 students to an 80 student class. The 32 student pilot had a high faculty-student ratio. Would the program work with 80 students and a lower faculty-student ratio, or was the success due only to the small size of the pilot? Thus, the faculty focused on how the increase could be accomplished while still maintaining positive outcomes for the students.

In this paper, the instructors show how scaling up the pilot project affected course material, delivery of that material, engineering projects, and student-instructor relationships. Next, the paper discusses how a physical facility was designed to accommodate this increased class size and closes with overall assessment data. The paper focuses on the efforts made in English, physics, engineering and calculus since these subjects made the most significant changes. Because both the new classroom and the original pilot room furnishings could not accomodate liquids, in both the original pilot and in the scaled-up version, the lab portion of the class had to be held in the University's traditional chemistry labs which accommodate maximum sections of 24 students. Therefore, Chemistry has remained unaffected by the scaled-up class.

Scale-up in English Composition

The courses least affected by scale-up, from the rest of the FIPE team's viewpoint, are the composition courses (ENG 101, 102). Because these course are normally taught to groups of 25 students or less, an 80 student class was truly radical. Composition teachers usually pride themselves on the small-class atmosphere they manage to create, and 80 students in one room seemed to severely restrict that. The administration suggested changing the format of the three weekly meetings by holding one with the whole class and the other two sessions as smaller breakout or recitation sections. This seemed the only way to maintain what was considered an integral part of teaching composition.

However, the English teachers on the FIPE team felt that their experience with the pilot class proved they could deliver their material to a larger class and maintain the small group atmosphere. Indeed, since the other classes in the integrated program would be taught to the full class, they felt that it was imperative English be taught in the same manner. They could envisage a multitude of problems, from inconsistent teaching and grading, having to resolve student preferences for a particular teacher if they broke the class into small sections, and having to split up teams (a considerable portion of the class work is done in teams), which would engender many logistical nightmares.

To avoid these difficulties, the English teachers decided to keep all of the students in the same room with all three teachers and employ a method of team teaching that would ensure that all students experienced the same teacher and that each student was graded by each teacher. Thus, all three teachers attended each class session. One teacher assumed the lead role for a block of lessons (usually a set leading to a single paper), and the other two teachers played a supporting role in the planning and delivery of that material. The English teachers met each week to do the detailed planning of lessons, and then, in class, the lead teacher conducted the lesson. The other two teachers acted as helpers, ensuring that students remained on task, and answering questions that arose. When the lead teacher discussed a particular topic, the helpers added their own thoughts, and often played the role of student to ask questions that they felt students might have but not ask.

This method of team teaching led to a very interactive classroom. As lead teacher, each has found that the helper teachers asked key questions. Moreover, students enjoyed the interchanges that developed when the helper teachers, offering a very different point of view, sometimes challenged what the lead teacher stated. This assuming of the devil's advocate role provided students with a model for their own groups so that this team teaching allowed the English teachers to model the kind of team interaction they wished students to develop. The students also knew that when the English teachers discussed how best to manage teams, the kinds of problems teams have, and ways to resolve conflict, they were speaking from their own team experience.

Despite that apparent success of managing an 80 person classroom through team teaching with three teachers, the class only worked because the teachers employed active and cooperative learning. Had the teachers attempted to employ a traditional Socratic mode with the 80 student class, the composition class would not have worked. A single teacher could not interact with 80 students in the way that she could in the traditional composition class where the ratio is one teacher to 25 students. Therefore, the English teachers assigned a group of students to an instructor to whom they should go for help prior to submitting any assigned paper, and who would eventually grade those papers. In this way, no one teacher was overwhelmed, and since assignments to a teacher were changed for each paper, this meant that each student had at least one paper graded by each teacher, thus ensuring some degree of equality.

To further ensure equality in standards, the English teachers met routinely and went over grading standards for each assignment, sometimes grading several papers together to ensure that they were all setting the same standards. This obviously takes more time than does a traditional composition class in which the teacher also does all of the grading. Despite this extra time commitment, the English teachers found some enormous benefits to the large class and the three person teaching team.

Scale-up in Physics

A "Self-Contained" Physics Laboratory

The laboratory portion of the physics course presented major scale-up issues in terms of space and equipment. The 32-student pilot programs were able to use the regular physics lab rooms and equipment. Furthermore, the pilot program classroom was located immediately adjacent to the student labs, allowing students and laboratory equipment (oscilloscopes, function generators, etc.) to move back and forth easily. As a result, much of the lab work was actually conducted in the classroom using equipment from the labs.

The classroom for the scaled-up 80-student program, in marked contrast, is situated far from the student labs and the previous mode of operation became impractical. Moreover, use of the standard labs would have necessitated splitting the class into several different laboratory sections and relegating much of the lab teaching duties to teaching assistants. Hence the physics instructor decided to try and fit the physics laboratory into the classroom rather than to fit the class into the physics lab rooms. This required the physics laboratory to become "self-contained" within the new classroom.

Doing this for the mechanics semester presented little difficulty. Given the presence of computers in the classroom and the commercial availability of equipment and software specifically designed for introductory physics teaching [4,5], it was relatively uncomplicated to design “self-contained” mechanics experiments. Twenty sets of Pasco's Introductory Dynamics System [5] were purchased, along with MultiPurpose Lab Interfaces™ (MPLI), Motion Detectors, Force Sensors and MPLI Software for Windows™ from Vernier Software[4]. Table I of Appendix A (found in the CD version of the proceedings), provides a complete list of the equipment. The equipment cost about $900 per team. Laboratory assignments designed around this equipment emphasized “problem-solving” skills in contrast to the more “recipe-based” experiments of standard introductory physics lab courses [6].

Appropriate laboratory experiments for the electricity and magnetism semester initially appeared more difficult to develop, given the sophisticated and expensive electronics gear usually required (oscilloscopes, function generators, amplifiers, etc.). In fact, it became clear that much of this gear could be supplanted by the computer and MPLI. The MPLI functions very well as an oscilloscope provided the time scale of experiments is made milliseconds or greater. Simple integrated circuits can be assembled by the students on electronic “breadboards” to replace function generators and other electronics equipment. Though viewed initially with some trepidation, the IC breadboard circuits proved remarkably successful. With inexpensive but very “high-tech” electronics parts and using the “Plotter/Graph” or “Oscilloscope” window of the MPLI, the electricity and magnetism semester was thus made “self-contained” at a cost of about $400 per team. Table II, in Appendix A, lists the contents of the electronics parts kits.

Integrated circuits (notably the 741 IC operational amplifiers for signal amplification and 555 IC timers for pulse generators) were introduced in the first week of the semester and used in a variety of breadboard applications throughout the semester. Initially, the ICs were presented to the students as complete “black boxes.” Once Kirchhoff's Laws had been introduced, however, the op-amps could be revisited and understood. In the team final exam project for the semester students were required to construct an analog op-amp integrator to solve Newton's Law of Cooling for a time-varying ambient.

A priori, it was entirely unclear whether, in a classroom containing 20 teams of four students each, it would be possible to assemble working IC "breadboard" circuits within a reasonable period of time. This turned out to not be a problem. If provided with a schematic and an actual picture of the desired circuit, the student teams could assemble a clone of a simple op-amp circuit in about 45 minutes (digital photos are recorded and placed on the classroom server, providing a color image which greatly helps in the assembly of the circuits). Whatever troubleshooting was necessary could easily be handled by the professor and a single teaching assistant circulating around the room. The basic IC circuits were left assembled on the breadboards for the entire semester and used in multiple experiments. Modern ICs are virtually indestructible and damage losses for the entire semester comprised no more than a dozen burned out IC's and one failed breadboard power supply.

Thus, in a classroom equipped with computers, it is possible to carry out virtually any “standard” introductory physics laboratory experiment. Moreover, it is possible to undertake experiments that *cannot* be carried out in the *standard* student lab rooms. This is particularly true in the electricity and magnetism semester once simple integrated circuits have been introduced. The presence of laboratory equipment in the classroom makes it possible to incorporate hands-on lab activities into the class work. A single professor, aided by a teaching assistant, is able to handle a two-hour laboratory session for a class of 80 students. The equipment problem anticipated by scale up seems to have been surmounted with success. The concept of a “self-contained” laboratory seems to be valid and useful.

Scale-up in Engineering

The engineering component of the FIPE course is divided into three components. These are (a) an introduction to <u>engineering design</u>, (b) an introduction to <u>modeling</u>, and (c) integrated <u>engineering projects</u>. The first two portions, design and modeling, were taught in a scripted environment. That is, the two-hour course period was carefully divided into time slots in which a variety of tasks were scheduled. All of the class scripts were listed on a course WWW site, which the students could access on the workstations at their tables. The scripting brings about an orderly environment - the students are aware of their tasks and when they must be completed - but it also made the environment quite dynamic and lively as student teams compared the work they generated in class. This approach worked extremely well in the larger engineering class.

In the engineering project component, students were asked to design, model, build, operate, and test an engineered artifact that integrates the physics, calculus, and rhetorical skills that the students have learned up to that point. In the pilot sections, when the class size was smaller, students were allowed to use the engineering machine and wood shops to construct projects. This was impossible with the scaled-up class, so twenty sets of metal construction parts (made by Meccano™) were purchased and the students were instructed to use these to make the artifacts. This approach provided both engineering constraints (limited availability of parts and part sizes) and an opportunity for engineering creativity. These kits were used to construct a catapult to launch a squash ball and a trebuchet to throw a golf ball. All of the teams were able to build workable scale models, and many of the teams showed remarkable ingenuity in using the limited part set.

Although the task of delivering the engineering content of the integrated course to a scaled-up class appeared to be daunting at first, the engineering faculty chose an approach that resembled the engineering process itself. They divided the engineering course into smaller components, examined the solution space systematically, and determined that a carefully orchestrated structure would produce an orderly and successful class. Additional details concerning the engineering component of the scaled-up class, including the scripted classes and the project descriptions, can be found at *www.eas.asu.edu/~roedel/ece100a/index.html*

Scale-Up in Calculus

The logistics of scaling up was not as complicated in calculus as it was in the physics and engineering courses. Much of the class was taught in a discovery learning format which presented some new challanges with a class of nearly 80 because freshmen students feel very strongly that learning mathematics is an individual competetive endevor. The more successful results came from the cooperative team projects,where group work was essential to complete the assignment. For example, when studying limits of rational functions, each member of a team of four studied a different aspect: holes, vertical asymptotes, zeros and end behavior. After they had all assimulated the material, they had to construct functions to represent graphs.

Scale-up of the Classroom

Appropriate classroom space for the program was essential. While it is difficult to prepare students for the modern workplace environment by teaching in traditional lecture halls with a blackboard and/or an overhead projector, it would impossible to conduct the integrated course being reported on in this paper in a traditional classroom. The first two years of the integrated freshman class were taught in a room that had 26 sq. ft of gross floor space per student. Because the room had only 18.5 sq. ft per student of usable floor space (excluding table surfaces), it was too congested for the instructor to move freely among the students.

The scaled-up class was taught in a newly remodeled, experimental classroom that has proven its usefulness. Student tables for this room were custom designed, built, and installed to allow teams of four students to interact with each other and with technology. Although there is one sq. ft less of gross floor area per student between the pilot classroom and the scaled-up classroom, the 3 sq. ft difference of usable floor space leads to a considerable improvement in managing the active classroom. A good part of the success of the scale-up resulted from the layout and functionality of this fully mediated room. More information, including engineering drawings of the student tables, a floor plan showing table layout, a photograph of the room in use, and a list of the software available, can be found at *www.eas.asu.edu/-~asufc/-Classrooms/-classroom.html.*

Effects on Student-Student Interaction

Despite some of the benefits of scale-up, the FIPE team noticed some differences in the interaction between students in the scaled-up version compared to the pilot programs. The students themselves initially found it hard getting to know their peers in the class. Students get to know their team members quite well, due to the heavy team emphasis in the integrated program. Each student participates in three different teams over the course of a semester; thus, each student gets to know up to nine other class members quite well. But they find it more difficult to get to know the other 70 students in the scaled-up class. The faculty is working on strategies to improve cross-team interaction.

Effects on Student-Faculty Interaction

Student-faculty interaction has also been affected. During the initial weeks of the first semester, all the faculty complained that the sheer number of students in one class was overwhelming and that it was much harder to put names to faces than in the small pilot classes. In addition, even after the faculty learned student names, they found that they had to make a special effort to ensure communication with all students on a regular basis in and out of the classroom. In the classroom, this meant keeping a record of who reported out for the team. It is too easy for a small group to dominate if this is not done. Moreover, it was especially easy to neglect the women, some of whom are naturally more reticent in a class in which they are out-numbered 5.5 to 1.

Furthermore, since accountability of individual students was more difficult to maintain in the larger class size, ensuring that all students were "pulling their weight" and keeping up with the course was harder. In the two fall semesters of small pilots, only one student quit coming to class. In the fall semester of the scaled-up class, a total of three students dropped out. However, judged by the fact that 75% of the fall semester class in the large scale-up experiment went on to register for the spring semester,[7] whereas 74% of the small-pilot students registered for the spring semester, there is no noticeable difference in student perception about the value of the class.

Outside class, faculty-student interaction was harder to maintain with the scaled-up size. Since many students who are not experiencing academic problems do not come to office hours, one successful solution the instructors employed was to hold some of their office hours in the classroom after the classes ended rather than in their offices. It proved to be an invaluable way of becoming acquainted with more students and did help faculty-student interaction.

Overall Assessment

The Mechanics Baseline Test and the Force Concepts Inventory tests were employed as assesment tools in physics [8]. Both were given at the beginning ("pre test") and then again at the end ("post test") of the first semester. Performance of the scaled-up 80-student cohort was compared with that of the 32-student pilot groups and with the performance of ASU introductory physics students in general. Results for the FCI are tabulated below. The "Gain" figure gives the student's pre- to post-test improvement relative to his/her maximum possible improvement. It appears that the 80-student class is actually performing somewhat better than the 32-student pilot sections. Scale-up has apparently had no negative effect on learning within the physics component of the Foundation Coalition.

Table 1: Force Concept Results to Date for Pilot and Scaled Up Class

FORCE CONCEPT INVENTORY (Grade scale of 0-100)						
Year	**Class Size**	**FCI Pre-Test**		**FCI Post-Test**		**Gain**
	(#)	**AVG**	**S.D.**	**AVG**	**S.D.**	**AVG**
F94	32	**51.0**	17.2	**65.2**	14.1	**0.29**
F95	32	**49.7**	19.3	**59.3**	20.3	**0.19**
F96	80	**46.7**	15.6	**63.8**	17.6	**0.32**
ASU typ.	130 typ.	**52**	19	**63**	18	**0.23**

Table 2: Grade Comaprison for Scaled Up Class 96-97 and Pilot Program 95-96

Fall Semester GPAs of Freshman FC Students						
	ECE100	ENG101	MAT270	PHY121	PHY122	Total
1995-1996	2.90	2.80	2.52	2.13	3.03	2.68
1996-1997	2.93	2.94	3.00	2.25	2.89	2.80
Spring Semester GPAs of Freshman FC Students						
	CHM114	ENG102	MAT271	PHY131	PHY132	Total
1995-1996	3.33	3.24	2.62	2.24	3.62	3.01
1996-1997	2.93	3.18	2.28	2.26	2.76	2.68

Overall grades for English for the scaled-up class improved in the fall compared to the second year of the pilot program and remained close for the spring as they did in the other classes (see Table 2). However, a more revealing measure than grades is whether students met the objectives of the course. Of those objectives, the most important significant, according to research, is the ability to develop and write for an audience other than their teachers and their peers [9]. To assess this, students were graded on how well they met audience's needs and on their ability to create their own rhetorical situation which they submitted for grading [10]. All the students demonstratied a sense of audience awareness and translated that awareness into rhetorical problems they then solved in the paper. This particular set of tasks is very demanding, and in many composition sections taught outside the FIPE program, students write almost exclusively for their peers and teachers. These results in English suggest that the students suffered no deleterious effects from the scaled-up class.

Reflection

Although scale-up has been has been relatively painless, it has required greater management skills and better record keeping. But fears about class size have been allayed. In fact, the team discovered that students' perceptions of the class size are not dependent on actual numbers, but on what they are accustomed to. For example, in the spring '95 semester the pilot class was surveyed to sense their perceptions. After a semester in the small size class (31 students), students thought the ideal size was 39.8 students, (average of all responses) - minimum response of 30, maximum of 80, standard deviation of 13. In the fall '96 semester, when the same survey in the scaled-up class was repeated, students thought the ideal size was 82.7 students (average of all responses) - minimum response of 40, maximum of 140, standard deviation of 17. Thus students' acceptance of the class size appears to relate to how faculty perceive the class size and how well they adapt their teaching. It probably also has to do with how well the room accommodates activities. If the room is designed with a large, active, computerized, class in mind, and the faculty consider how they will adapt their teaching to a large scale, scale-up can work.

As a part of the same survey, the students were asked to rate 16 different items with respect to importance to their educational experience. A Likert scale of 1 to 5 was provided (1=Very Detrimental; 5=Very Important). Figure 1 shows the results sorted from most important to least based on the average responses of the large class. Only small differences between the small pilot class and the larger scaled-up class are apparent. Clearly, both groups value the "Sense of Being at the Forefront of Educational Innovation," "Computers in the Classroom for Student's Use," access to computers outside of class, and "Engineering Projects."

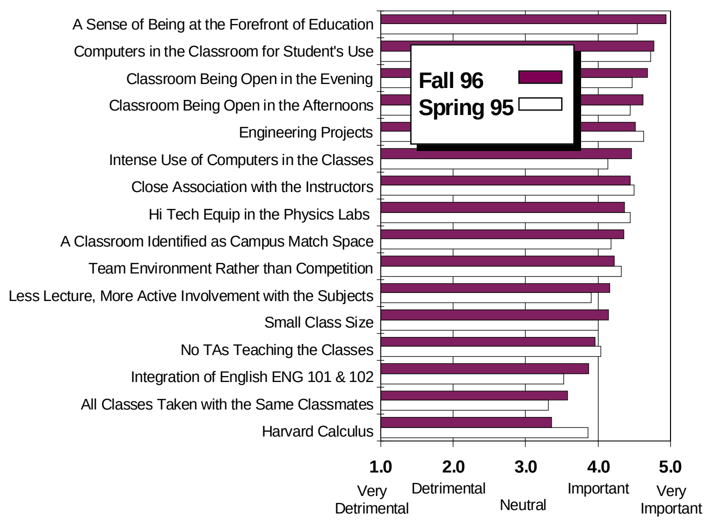

Figure 1 : Student Perceptions of What is Important to Their Educational Experience

Provided that scale-up is done in a way that pays attention to these elements and the others in the list (all were rated, on the average, above "Neutral"), the learning of students should not be jeopardized. If instructors put the emphasis on the learner and are willing to use teaching styles other than the "expert" lecturer, differences in student learning and attitudes for class sizes between 32 and 80 should be small.

Acknowledgments: This work was supported, in part, by the National Science Foundation through the *Foundation Coalition* under Cooperative Agreement EEC92-21460 and by the ASU College of Liberal Arts and Sciences, 1995-96 Grant Award Program to Advance the Quality of Undergraduate Education

References

[1] The Foundation Coalition is an NSF-funded group of 7 institutions of higher education: Arizona State University, Maricopa Community College District (AZ), Rose-Hulman Institute of Technology, Texas A & M University-College Station, Texas A & M University-Kingsville, Texas Women's University, University of Alabama-Tuscaloosa.

[2] Information on the Foundation Coalition, its thrusts and goals, can be found at *//foundation.ua.com*

[3] For more information, see also:
D. L. Evans. "Curriculum Integration at Arizona State University," Proceedings, IEEE/ASEE FIE '95, Atlanta, 1995.
R. Roedel, M. Kawski, B. Doak, M. Politano, S. Duerden, M. Green, J. Kelly, D. Linder, and D. Evans, "An Integrated, Project-based, Introductory Course in Calculus, Physics English and Engineering," Proceedings, IEEE/ASEE FIE '96, Atlanta, 1995.
B. Doak, J. McCarter, M. Green, S. Duerden, D. Evans, R. Roedel, and P. Williams, "Team-Based Projects for Assessment in First-Year Physics Courses Supporting Engineering," Proceedings, IEEE/ASEE FIE '96, Salt Lake City, 1996.
R. J. Roedel, D. Evans, R. B. Doak, M. Kawski, M. Green, S. Duerden, J. McCarter, P. Williams, and V. Burrows, "Use of the Internet to Support an Integrated Introductory Course in Engineering, Calculus, Physics, Chemistry, and English," Proceedings IEEE/ASEE FIE '96, Salt Lake City, 1996.
S. Duerden and M.Green, "Enhancing Freshman Engineering Education: Integrating Freshman English Composition with Engineering, Math, Physics, & Chemistry," Proceedings, IEEE/ASEE FIE '95, Atlanta, 1995.

[4] Vernier Software, *//www.teleport.com/~vernier.*

[5] Pasco Scientific, *//www.pasco.com.*

[6] See P.W. Laws, *Workshop Physics Activity Guide*, Wiley, New York, 1997 and L.C. McDermott, *Physics by Inquiry*, Wiley, New York, 1996.

[7] There are several reasons why students did not register for the second semester: courses caused too heavy a load, failing one or more of the courses in the first semester, or finding that engineering is not for them. Many who did not register for the FIPE program in the second semester registered for the traditional courses in engineering. A few changed their major; very few dropped completely out of the University.

[8] D. Hestenes, M. Wells, & G. Swackhamer, "Force Concept Inventory," *The Physics Teacher*, 30, March 1992, and D. Hestenes & M. Wells, "A Mechanics Baseline Test," *The Physics Teacher*, 30, March 1992.

[9] U. S. Department of Education. *National Assessment of College Student Learning: Identifying College Graduates' Essential Skills in Writing, Speech and*

Listening, and Critical Thinking. Office of Educational Research and Improvement. NCES 95-001, 1995, pp. 31-35.

[10] See M. Green and S. Duerden, "Collaboration, English Composition & the Engineering Student: Constructing Knowledge in the Integrated engineering Program," Proceedings, IEEE/ASEE FIE '96, Salt Lake City, 1996.

Appendix A: Laboratory Equipment for "Self-Contained" Physics Laboratory Freshman Integrated Program in Engineering

Table I. Laboratory Equipment for Mechanics Semester			
Equipment per Computer (1 Computer per 2 Students)			
Qty.	**Supplier**	**Cat. No.**	**Description**
1	Vernier	MP-WIN	MPLI Package w/ Windows
1	Vernier	SFS-DIN	Student Force Sensors
1	Vernier	MD-M	Motion Detectors
2	Vernier	TL-DIN	Test Leads
1	Pasco	ME-9430	Plunger Cart
1	Pasco	ME-9454	Collision Cart
1	Pasco	ME-9485	Fan Cart
1	Pasco	1.2 m	1.2 m Track for Carts
1	Pasco	-	Fixed End Stop/ Leveling Screw (for Track)
1	Pasco	ME-9469	Adj. End Stop (w/ Magnets and Velcro Pads)
1	Pasco	ME-9448A	Super Pulley with Clamp
1	Pasco	-	Neodymium Magnets (for Plunger Cart)
3	Pasco	632-04978	Harmonic Springs
1	Pasco	-	Friction Block (w/ 2 different surfaces)
1	Pasco	-	Rod Clamp (for Tilting the Track)
2	Pasco	-	500-g Masses (fit onto Carts)
1	Pasco	SE-9451	Small Base and Support Rod
1	Pasco	SE-9442	Multi-Clamp
1	Pasco	SE-9445	Three-Finger Clamp
1	Pasco	ME-9348	Mass and Hanger Kit
1	Cole-Parmer	G-0847-20	Double Clamp
1	Sargent-Welch	S-78430-10	Support Rod Table Clamp
1	Sargent-Welch	S-78454-B	Al Support Rod, 30 cm
1	Sargent-Welch	S-784554-D	Al Support Rod, 60 cm
1	Cenco	73115U	Meterstick
1	Cenco	32177U	Centimeter Ruler
1	Cenco	31167U	Dial Calipers
1	Cenco	88430-1U	Torpedo Level
1			Protractor
The classroom was equipped with one set each of the following			
3	Edmund Scientific	39716	Electronic Balance, 1 g resolution (3x for entire class)
2	McMaster-Carr	45964T15-	Metal Cabinets, 48" x 24" x 72" (2x for all Lab Equipment)

Table II. Laboratory Equipment for Electricity and Magnetism Semester			
Equipment per Computer (1 Computer per 2 Students)			
Qty	**Supplier**	**Cat. No.**	**Description**
2	Circuit Specialists	PP-272	Breadboard, Built-in Power Supply
2	Circuit Specialists	WK-1	Wire Jumper Kit
2	Circuit Specialists	DT3800	Multimeter
1	Circuit Specialists	HT-108	Cutter and Stripper
1	Circuit Specialists	08-702	Miniature Long-Nosed Pliers
1	Circuit Specialists	9101A	Screwdriver, Flat Point
1	Circuit Specialists	WT25H1	Soldering Iron
1	Circuit Specialists	RH60-TUBE	Solder
1	Circuit Specialists	EX-1	IC Extraction Tool
2	Circuit Specialists	950W1K	Cermet Trim Pots, 1K
2	Circuit Specialists	950W10K	Cermet Trim Pots, 10K
2	Circuit Specialists	950W1M	Cermet Trim Pots, 1M
2	Circuit Specialists	70F823A1	RF Choke, 8.2 mH
2	Circuit Specialists	70F222A1	RF Choke, 22 mH
2	Circuit Specialists	25RF120	Speaker, 8 ohm, 2" dia.
2	Circuit Specialists	25LM040	Microphone Elements
4	Circuit Specialists	2N2222A	Transistor, NPN
4	Circuit Specialists	2N3906	Transistor, PNP
4	Circuit Specialists	2N3904	Transistor, NPN
2	Circuit Specialists	J4-805	CdS Photocell
4	Circuit Specialists	L934HD	LED, Red
2	Circuit Specialists	334-3827-102	NTC Thermistors, 1 kohm
4	Circuit Specialists	TA-C002	Tantalum Capacitors, 0.22 uF
4	Circuit Specialists	TAC005	Tantalum Capacitors, 1 uF
4	Circuit Specialists	TAC006	Tantalum Capacitors, 2.2 uF
3	Circuit Specialists	TAC009	Tantalum Capacitors, 22 uF
20	Circuit Specialists	RC10	Metal Film Resistors, 10 ohm
20	Circuit Specialists	RC100	Metal Film Resistors, 100 ohm
20	Circuit Specialists	RC1000	Metal Film Resistors, 1 kohm
20	Circuit Specialists	RC10K	Metal Film Resistors, 10 kohm
20	Circuit Specialists	RC100K	Metal Film Resistors, 100 kohm
2	Circuit Specialists	LM555	Timer IC
4	Circuit Specialists	MC1741CP1	741 Op Amp
20	Circuit Specialists	1N914	Diodes
4'	Newark Electronics	2855/1-2	Hook-Up Wire, 22 AWG Solid,, Black
4'	Newark Electronics	2855/2-3	Hook-Up Wire, 22 AWG Solid,, Red
2	Newark Electronics	35F1001	Mini-Grabber Test Clips, Black
2	Newark Electronics	35F1002	Mini-Grabber Test Clips, Black
1	Newark Electronics	97N8305	Utility Box, Polypropylene
4	Newark Electronics	39N863	Banana Plugs, Red
4	Newark Electronics	39N864	Banana Plugs, Black