Experimental Hybrid Courses That Combine On-Line Content Delivery with Face-to-Face Collaborative Problem Solving

Cordelia M. Brown <brown83@purdue.edu>
David G. Meyer <meyer@purdue.edu>
Purdue University
School of Electrical & Computer Engineering
West Lafayette, Indiana 47907

Abstract

An experimental format is described in which the "lecture content" for core sophomore- and junior-level ECE courses was delivered via on-line streaming video (referred to as “virtual lecture”), and the regularly-scheduled class meeting times were used for instructor-directed, collaborative problem solving sessions (referred to as “directed problem solving”). Traditional lecture divisions of each course were offered simultaneously, to provide students an opportunity to select the course format they felt best matched their individual learning style. The on-line Index of Learning Styles (ILS) tool was used to help students decide which course format to choose. Results, including survey data and comparative performance on common exams, are presented for the initial trials conducted.

Introduction

The goal of this work was to compare the relative effectiveness of the “traditional lecture” format with non-traditional “hybrid” course formats, specifically in which the roles of in-class and outside-of-class activities were largely “reversed”. So-called “inverted” course formats were created for two core computer engineering classes: a sophomore-level *Introduction to Digital Systems Design* course, and a junior-level *Microprocessor System Design and Interfacing* course. Both of these are 4-credit hour courses that include an integrated laboratory.

In the experimental formats, the basic lecture content was delivered asynchronously via streaming video, while collaborative solving of homework problems accompanied by a detailed walkthrough of their solutions was done synchronously (i.e., during scheduled class periods) – which we refer to as *directed problem solving* (DPS). Traditional assigned (outside-of-class) written homework was replaced by collaborative problem solving by students working in small teams (of two students each). Solutions devised by the various teams were evaluated "on the spot" through "self-grading" (based on an instructor-directed solution walk-through), thus providing immediate feedback and eliminating the time, overhead, and expense associated with homework paper collection and grading. Students' scores for the "homework" part of the course grade were determined based on attendance at their assigned DPS section.

For the trials completed thus far (one for the sophomore-level course and three for the junior-level course), a traditional lecture division was run in parallel with the experimental DPS division. For the junior-level course, the experimental division was split into multiple sections that each met once/week in lab, facilitating small recitation-style “studio” settings for the DPS sessions. For the sophomore-level course, the experimental division met twice/week in a small classroom (since a “studio” of sufficient size was not available for the DPS sessions).

Beginning with the trials conducted Fall 2006, students were instructed to use the Index of Learning Styles (ILS) tool to help them decide which course format might potentially best match their learning style. Specifically, students with some combination of active, visual, and/or global preferences were encouraged to consider choosing the DPS option. While allowing students a choice of course format may have introduced some bias in the exam performance results obtained, an important finding of this initial study was the fraction of each cohort that elected the non-traditional option (and the rationale for doing so, based on exit survey results).

A key, underlying goal of this project was to gain an understanding of how efficiently and effectively students learn in hybrid course environments relative to those that are more traditional. This outcome was evaluated by comparing scores on common exams. Another goal was to accommodate a wider diversity of learning styles by offering students a choice between two, very different course formats – based on the premise that being required to make a choice forces students to think about how they learn and the environment in which they learn best. This outcome was evaluated based on exit survey data.

Results for Junior-Level Course (Three Trials)

The results obtained for three successive trials of the junior-level course, conducted Fall 2005, Spring 2006, and Fall 2006, are described first. In the Fall 2005 and Fall 2006 trials, the same instructor taught the traditional lecture division as well as both sections of the DPS division. In the Spring 2006 trial, a different instructor taught the traditional lecture division while the former instructor taught both sections of the DPS division. The cohort sizes for the Fall 2005 trial were 29 and 55 for the traditional lecture (TL) and the directed problem solving (DPS) divisions, respectively. For the Spring 2006 trial, the corresponding cohort sizes were 23 and 44. Finally, for the Fall 2006 trial, the cohort sizes for the TL and DPS divisions were 54 and 43, respectively. As documented in Table 1, the prerequisite course GPA of the TL and DPS cohorts differed by no more than 0.3 (on a 4.0 scale).

One significant difference implemented Fall 2006 in the traditional lecture division was incorporation of in-class, collaborative homework problems. We believe this prompted more students to choose the traditional lecture version of the course in this latter trial (relative to previous trials), based on success achieved with this methodology in the pre-requisite sophomore-level (*Introduction to Digital System Design*) course the previous semester. Another significant difference instituted Fall 2006 was utilization of the on-line Index of Learning Styles (ILS) tool, in an effort to help guide students into the division that best matched their individual learning style.

There are three primary learning outcomes in the junior-level course, each of which is assessed using a comprehensive, in-lab practical exam: (1) an ability to write programs for a computer in assembly language, (2) an ability to interface a microprocessor to various devices, and (3) an ability to effectively utilize the wide variety of peripherals integrated into a contemporary microcontroller. Each exam consists of three components: (a) standardized multiple-choice questions that gauge understanding of content; (b) analysis/design questions that gauge basic skills; and (c) application programming questions that gauge more advanced (synthesis) skills. Further information about the methodology used to assess these outcomes is provided in [1].

Comparative exam performance results for each of the three trials conducted in the junior-level course are given in Tables 2-5. Tables 2-4 provide a comparison of the traditional lecture

(TL) and directed problem solving (DPS) divisions for the various categories of exam questions (described above), while Table 5 provides a three-trial summary of the overall exam performance. Cases for which exam performance was better in the TL division are shaded in blue, while those for which exam performance was better in the DPS division are shaded in green. For Trials 1 and 2, the DPS divisions generally outperformed the TL divisions; for Trial 3, this trend basically reversed. Note, however, that the Trial 3 DPS performance did not degrade relative to the other two trials; rather, it improved. Instead, the incorporation of collaborative problem solving exercises into the traditional lecture made a dramatic improvement in that division's exam performance relative to the previous two traditional lecture trials.

In addition to comparing exam performance, a detailed exit survey was conducted in both divisions for each trial. Tables 7-12 document the survey questions and responses obtained. One interesting result is that about one-half of the students in the TL division (8 out of 14, Spring 2006) used the on-line lectures *instead of* attending the "live" lectures. For that trial, only 3 of the 14 respondents felt like they could have *learned the course material better in a traditional live lecture* format than in a "virtual" (online) format (12 out of 21 TL students answered this question affirmatively Fall 2005, along with 14 out of 36 TL students Fall 2006). A somewhat disappointing result is the number of students who selected their course format "by default" (i.e., based on the division to which they were initially randomly assigned): this was apparently the case for 14 out of 21 TL students Fall 2005, 9 out of 14 TL students Spring 2006, and 21 out of 36 TL students Fall 2006. This would seem to indicate that use of the ILS survey, effective with the Fall 2006 trial, had little influence on students' choice of course format.

On the DPS division surveys, an overwhelming majority (36 out of 46, Fall 2005; 27 out of 29, Spring 2006; and 25 out of 31, Fall 2006) believed that the *on-line lecture and directed problem solving combination helped them learn the course material better*. A similar majority affirmed that they *would choose the on-line lecture and directed problem solving combination* in another ECE course, were it available (31 out of 46, Fall 2005; 23 out of 29, Spring 2006; and 24 out of 31, Fall 2006). Another noteworthy response on the DPS surveys concerns the "enjoyment" factor: a significant majority indicated that they *enjoyed learning the course material* in the directed problem solving format (39 out of 46, Fall 2005; 24 out of 29, Spring 2006; and 25 out of 31, Fall 2006).

Results for Sophomore-Level Course (One Trial)

The results for the initial trial of the sophomore-level course, conducted Fall 2006, are described next. Because the traditional lecture (TL) and directed problem solving (DPS) divisions were scheduled to meet at the same time, two different instructors were involved (one dedicated to each division). The cohort sizes were 94 and 31 for the TL and DPS divisions, respectively. Like the third trial of the junior-level course described above, the traditional lecture division featured regular in-class collaborative problem solving exercises.

There are six primary learning outcomes in the sophomore-level course, each of which is assessed using an in-class "hourly" exam: (1) an ability to analyze static and dynamic behavior of digital circuits; (2) an ability to represent Boolean functions in standard forms, to map and minimize them, and to implement them as combinational logic circuits; (3) an ability to use a hardware description language to specify combinational logic circuits, including various "building blocks" such as decoders, multiplexers, encoders, and tri-state buffers; (4) an ability to

design and implement arithmetic logic circuits; (5) an ability to analyze, design, and implement sequential circuits and use a hardware description language to specify them, including various "building blocks" such as counters and shift registers; and (6) an ability to design and implement a simple computer. The exams generally consist of two components: (a) standardized multiple-choice questions that gauge understanding of content, and (b) application ("work out") questions that gauge more advanced (synthesis) skills. Further information about the methodology used to assess these outcomes is provided in [1].

Results for the initial sophomore-level trial are given in Table 6, comparing the traditional lecture (TL) and directed problem solving (DPS) divisions for the two categories of exam questions (described above). Cases for which exam performance was better in the TL division are shaded in blue, while those for which exam performance was better in the DPS division are shaded in green. Here, the DPS division outperformed the TL division on every outcome assessment exam, although the margin diminished somewhat as the semester progressed. A possible explanation is that several students, for whatever reason, simply stopped attending the DPS sessions about half-way through the semester, yet continued to "show up" for the exams. Given the relatively small sample size of the DPS division, two or three "non-participants" have the potential to significantly affect the aggregate exam performance. Another potential explanation is that, as the semester progressed, the TL instructor incorporated additional collaborative problem solving exercises into the lectures, thereby diminishing the advantage inherent in the DPS approach.

Exit survey results obtained for the sophomore-level course are documented in Tables 13-14. Similar to the junior-level trials, the course format choice "by default" was indicated by a significant majority of TL students: 53 out of 68. The Index of Learning Styles (ILS) survey apparently had limited influence on students' course format decisions: combined, only 25 out of 93 students indicated that the ILS survey *helped them choose the course format best for them.* Also similar to the junior-level survey results, only 20 out of 63 TL students felt they *learned the course material better in a traditional live lecture format*. On the DPS survey, an overwhelming majority (24 out of 25): (a) thought that the *on-line lecture and directed problem solving combination helped them learn the course material better,* and (b) said they *would choose the on-line lecture and directed problem solving combination in another ECE course* (if available). A similar majority (23 out of 25) said they *enjoyed learning the course material* in the DPS format, and that the *on-line lecture enhanced their learning experience.*

Summary and Future Work

Preliminary results, based on both exam performance and survey data, confirm the effectiveness of the experimental course format described in this paper relative to the "traditional lecture" format. The results also confirm the effectiveness of incorporating collaborative problem solving exercises into traditional classroom presentations. One might rightly conclude that, effectively done, there is potentially no significant difference in overall performance between a traditional lecture that incorporates regular in-class collaborative problem solving exercises, and a virtual (on-line) lecture format that features a recitation-style collaborative problem solving format. Assuming for the moment that this assertion is true, future studies related to this work might best focus on: (a) a comparison of the relative efficiencies of these two approaches (e.g., in terms of resource utilization); and (b) an analysis of which approach is "best liked" by students

(e.g., more frequent, less personal large-class meetings vs. less frequent, more personal small-class meetings).

An open question that remains concerns which approach, investigated in this study, is "better" or "worse" for a given student based on their individual learning style. To this end, one of the limitations of this study is an inability to fully decouple effects of the virtual and live lecture formats. This has been due to the public availability of the lecture videos on the course web sites. Another limitation is the potential for bias introduced by giving students a choice of course formats. For the junior-level course, both of these issues are currently being addressed: in the trial underway as of this writing (Spring 2007), only a traditional lecture format is being offered; in the subsequent trial planned (Fall 2007), only a directed problem solving version will be offered. This should effectively decouple course format choice as well as any latent effects of on-line lecture availability from the exam performance results recorded.

A more detailed analysis of how the Index of Learning Styles survey influenced students' course format choices, relative to the guidelines we provided, as well as how those choices (or "non-choices") may have impacted their exam performance would also be enlightening. Convincing students to make an *active choice* of course format (given this relatively unique opportunity offered to them in the computer engineering curriculum at Purdue), instead of merely a "default" choice, continues to be an area of concern. We may, in fact, not be realizing the full potential of the multi-format experimental offerings simply because students are not effectively choosing the instructional environment best suited for them. Hopefully a more effective strategy can be identified for use in future trials.

Finally, another open question concerns the type of "alternate-style" learners we are attempting to target in this study. As currently implemented, the "lecture" in both formats (traditional and virtual) is targeted for auditory-sequential learners. An interesting alternative would be to specifically target visual-spatial learners in the on-line (virtual) lecture format, to better complement what we are trying to achieve in the small group directed problem solving sessions (i.e., providing more of a "big picture" approach to problem solving, instead of simply lecturing on the sequence of steps involved). Perhaps this would provide a "higher contrast" learning environment than the traditional lecture/virtual lecture option currently offered.

References

[1] D.G. Meyer, "Strategies for Assessing Course-Specific Outcomes," *Proceedings of the 2006 American Society for Engineering Education Conference*, Paper 161 (June 2006).

[2] R.M. Felder and L.K. Silverman, "Learning and Teaching Styles in Engineering Education," *Engr. Education, 78*(7), 674-681 (1988).

[3] R.M. Felder and J.E. Spurlin, "Applications, Reliability, and Validity of the Index of Learning Styles," *Intl. Journal of Engineering Education, 21*(1), 103-112 (2005).

[4] R.M. Felder and R. Brent, "Understanding Student Differences." *J. Engr. Education, 94*(1), 57-72 (2005).

[5] R.M. Felder, "Matters of Style." *ASEE Prism, 6*(4), 18-23 (December 1996).

[6] R.M. Felder, G.N. Felder, and E.J. Dietz, "The Effects of Personality Type on Engineering Student Performance and Attitudes." *J. Engr. Education, 91*(1), 3-17 (2002).

Table 1. Prerequisite Course Grades (4.00 = A) for Junior-Level Cohorts.

	Exam Question Type					
	Trial 1 – Fall 2005		**Trial 2 – Spring 2006**		**Trial 3 – Fall 2006**	
	Traditional Format	Experimental Format	Traditional Format	Experimental Format	Traditional Format	Experimental Format
N	**33**	**55**	**24**	**44**	**54**	**43**
GPA	**3.01**	**2.82**	**2.55**	**2.85**	**2.75**	**2.67**

Table 2. Results for Junior-Level Trial 1, Fall 2005 (Traditional, N=33; Experimental, N=55).

	Exam Question Type					
	Standardized Concepts		**Basic Analysis**		**Application / Synthesis**	
Learning Outcome	Traditional Format	Experimental Format	Traditional Format	Experimental Format	Traditional Format	Experimental Format
1	**54.2%**	**60.6%**	**74.5%**	**81.5%**	**57.1%**	**62.9%**
2	**52.4%**	**52.7%**	**50.5%**	**52.8%**	**47.0%**	**55.0%**
3	**57.2%**	**58.9%**	**68.6%**	**65.8%**	**32.0%**	**37.3%**

Table 3. Results for Junior-Level Trial 2, Spring 2006 (Traditional, N=24; Experimental, N=44).

	Exam Question Type					
	Standardized Concepts		**Basic Analysis**		**Application / Synthesis**	
Learning Outcome	Traditional Format	Experimental Format	Traditional Format	Experimental Format	Traditional Format	Experimental Format
1	**42.9%**	**56.8%**	**79.5%**	**84.5%**	**59.9%**	**58.7%**
2	**51.5%**	**54.3%**	**59.2%**	**59.6%**	**46.5%**	**54.1%**
3	**55.8%**	**56.3%**	**71.9%**	**68.0%**	**52.8%**	**52.2%**

Table 4. Results for Junior-Level Trial 3, Fall 2006 (Traditional, N=54; Experimental, N=43).

	Exam Question Type					
	Standardized Concepts		**Basic Analysis**		**Application / Synthesis**	
Learning Outcome	Traditional Format	Experimental Format	Traditional Format	Experimental Format	Traditional Format	Experimental Format
1	**64.0%**	**60.0%**	**83.8%**	**77.9%**	**76.2%**	**74.7%**
2	**59.0%**	**58.6%**	**65.9%**	**67.4%**	**57.9%**	**66.9%**
3	**67.1%**	**64.0%**	**65.8%**	**60.8%**	**53.9%**	**57.0%**

Table 5. Summary of Exam Performance Results and Final Course Grades (4.00 = A) for Junior-Level Trials.

	Average Overall Exam Scores					
	Trial 1 – Fall 2005		**Trial 2 – Spring 2006**		**Trial 3 – Fall 2006**	
Learning Outcome	Traditional Format	Experimental Format	Traditional Format	Experimental Format	Traditional Format	Experimental Format
1	**64.8%**	**69.8%**	**63.3%**	**68.1%**	**75.7%**	**71.7%**
2	**48.9%**	**51.6%**	**49.9%**	**53.2%**	**61.1%**	**63.7%**
3	**47.2%**	**49.3%**	**55.6%**	**53.8%**	**59.5%**	**57.4%**
GPA	**2.10**	**2.50**	**1.98**	**2.30**	**2.35**	**2.39**

Table 6. Exam Performance Results for Sophomore-Level Trial, Fall 2006 (Traditional, N=94; Experimental, N=31).

	Exam Question Type					
	Standardized Concepts		**Application**		**Overall**	
Learning Outcome	Traditional Format	Experimental Format	Traditional Format	Experimental Format	Traditional Format	Experimental Format
1	**57.1%**	**70.4%**	**–**	**–**	**57.1%**	**70.4%**
2	**63.2%**	**69.6%**	**48.5%**	**56.9%**	**53.4%**	**61.6%**
3	**67.4%**	**73.4%**	**69.5%**	**74.1%**	**64.8%**	**70.8%**
4	**70.0%**	**71.0%**	**58.8%**	**62.2%**	**62.3%**	**64.5%**
5	**66.0%**	**64.4%**	**64.7%**	**72.5%**	**62.4%**	**63.8%**
6	**57.9%**	**61.3%**	**55.3%**	**56.8%**	**53.1%**	**55.6%**

Table 7. Survey Results for Junior-Level Trial 1, Fall 2005 (Traditional Lecture, N=21).

Question	*SA*	*A*	*N*	*D*	*SD*
1. I chose the traditional lecture option by default (or, because that was the division to which I was automatically assigned).	**5**	**9**	**5**	**1**	**1**
2. I would have chosen the directed problem solving/virtual lecture format if *that* had been the default option.	**6**	**8**	**3**	**3**	**1**
3. I was glad that I had a choice between two different course delivery options.	**4**	**7**	**9**	**0**	**1**
4. I used the on-line lectures *in addition to* attending the "live" class lectures.	**7**	**7**	**2**	**3**	**2**
5. I used the on-line lectures *instead of attending* the "live" class lectures.	**0**	**7**	**3**	**5**	**6**
6. The *Lecture Workbook* class note format helped me learn the course material.	**1**	**10**	**4**	**6**	**0**
7. I would prefer that the class notes *(Lecture Workbook)* be "filled in" rather than having to fill in the blanks during lecture.	**5**	**6**	**6**	**4**	**0**
8. I feel that I learn course material better in a traditional live lecture format than in a "virtual" (on-line) lecture format.	**3**	**9**	**1**	**5**	**3**
9. I would *not* consider taking *any* ECE course in a directed problem solving format.	**1**	**0**	**5**	**9**	**6**
10. Having a choice of course delivery options enhanced my ability to learn.	**0**	**9**	**12**	**0**	**0**
11. I took advantage of most of the on-line learning resources available for this course.	**6**	**11**	**2**	**1**	**1**
12. The practice homework sets and solutions helped me learn the course material.	**4**	**10**	**4**	**3**	**0**
13. The practice exams and solutions helped me learn the course material.	**5**	**13**	**1**	**1**	**1**
14. The modular, on-line ("virtual") lectures helped me learn the course material.	**6**	**10**	**3**	**1**	**1**
15. The on-line reference documents helped me learn the course material.	**7**	**14**	**0**	**0**	**0**
16. This course should *only* be offered in a traditional lecture format.	**0**	**1**	**9**	**8**	**8**

Table 8. Survey Results for Junior-Level Trial 1, Fall 2005 (Directed Problem Solving, N=46).

Question	*SA*	*A*	*N*	*D*	*SD*
1. The on-line lecture and directed problem solving session combination helped me learn the material better.	**13**	**23**	**7**	**2**	**1**
2. The on-line lecture and directed problem solving session combination helped me prepare for the *short answer and analysis questions* on exams.	**7**	**27**	**7**	**4**	**1**
3. The on-line lecture and directed problem solving session combination helped me prepare for the *programming questions* on exams.	**16**	**17**	**10**	**3**	**0**
4. The on-line lecture and directed problem solving session combination helped me prepare for the *laboratory experiments.*	**9**	**25**	**11**	**1**	**0**
5. I would choose the on-line lecture and directed problem solving session combination in another ECE course (if available).	**15**	**16**	**8**	**5**	**2**
6. I would prefer *only a live (traditional) lecture* over the on-line lecture and directed problem solving session combination for this course.	**3**	**6**	**13**	**17**	**7**
7. I would prefer a *live lecture and directed problem solving combination* for this course.	**10**	**21**	**6**	**8**	**1**
8. I enjoyed learning course material in the directed problem solving format.	**11**	**28**	**7**	**0**	**0**
9. I would prefer taking other courses with the directed problem solving format.	**13**	**21**	**10**	**2**	**0**
10. The directed problem solving sessions enhanced my learning experience.	**11**	**29**	**4**	**2**	**0**
11. I enjoyed interacting with my peers during the directed problem solving sessions.	**10**	**24**	**10**	**2**	**0**
12. I feel that most of the other students enjoyed learning in the directed problem solving format.	**8**	**28**	**10**	**0**	**0**
13. The on-line lecture enhanced my learning experience.	**6**	**21**	**13**	**5**	**1**
14. The on-line lecture prepared me for the directed problem solving sessions.	**3**	**26**	**14**	**3**	**0**
15. I viewed the on-line lecture before participating in the directed problem solving sessions.	**4**	**18**	**17**	**5**	**2**

Table 9. Survey Results for Junior-Level Trial 2, Spring 2006 (Traditional Lecture, N=14).

Question	*SA*	*A*	*N*	*D*	*SD*
1. I chose the traditional lecture option by default (or, because that was the division to which I was automatically assigned).	**3**	**6**	**3**	**2**	**0**
2. I would have chosen the directed problem solving/virtual lecture format if *that* had been the default option.	**2**	**5**	**5**	**1**	**1**
3. I was glad that I had a choice between two different course delivery options.	**2**	**7**	**4**	**1**	**0**
4. I used the on-line lectures *in addition to* attending the "live" class lectures.	**2**	**3**	**3**	**6**	**0**
5. I used the on-line lectures *instead of attending* the "live" class lectures.	**2**	**6**	**2**	**3**	**1**
6. The *Lecture Workbook* class note format helped me learn the course material.	**3**	**8**	**1**	**2**	**0**
7. I would prefer that the class notes *(Lecture Workbook)* be "filled in" rather than having to fill in the blanks during lecture.	**7**	**2**	**4**	**1**	**0**
8. I feel that I learn course material better in a traditional live lecture format than in a "virtual" (on-line) lecture format.	**2**	**1**	**6**	**4**	**1**
9. I would *not* consider taking *any* ECE course in a directed problem solving format.	**2**	**0**	**4**	**6**	**2**
10. Having a choice of course delivery options enhanced my ability to learn.	**2**	**4**	**6**	**2**	**0**
11. I took advantage of most of the on-line learning resources available for this course.	**5**	**6**	**1**	**2**	**0**
12. The practice homework sets and solutions helped me learn the course material.	**2**	**7**	**4**	**1**	**0**
13. The practice exams and solutions helped me learn the course material.	**6**	**5**	**3**	**0**	**0**
14. The modular, on-line ("virtual") lectures helped me learn the course material.	**5**	**7**	**1**	**1**	**0**
15. The on-line reference documents helped me learn the course material.	**4**	**6**	**2**	**2**	**0**
16. This course should *only* be offered in a traditional lecture format.	**1**	**2**	**4**	**5**	**2**

Table 10. Survey Results for Junior-Level Trial 2, Spring 2006 (Directed Problem Solving, N=29).

Question	*SA*	*A*	*N*	*D*	*SD*
1. The on-line lecture and directed problem solving session combination helped me learn the material better.	**10**	**17**	**1**	**0**	**1**
2. The on-line lecture and directed problem solving session combination helped me prepare for the *short answer and analysis questions* on exams.	**0**	**14**	**5**	**7**	**3**
3. The on-line lecture and directed problem solving session combination helped me prepare for the *programming questions* on exams.	**14**	**9**	**5**	**0**	**1**
4. The on-line lecture and directed problem solving session combination helped me prepare for the *laboratory experiments.*	**14**	**12**	**2**	**0**	**1**
5. I would choose the on-line lecture and directed problem solving session combination in another ECE course (if available).	**10**	**13**	**3**	**2**	**1**
6. I would prefer *only a live (traditional) lecture* over the on-line lecture and directed problem solving session combination for this course.	**1**	**2**	**5**	**12**	**9**
7. I would prefer a *live lecture and directed problem solving combination* for this course.	**11**	**7**	**7**	**3**	**1**
8. I enjoyed learning course material in the directed problem solving format.	**8**	**15**	**5**	**0**	**1**
9. I would prefer taking other courses with the directed problem solving format.	**7**	**16**	**5**	**1**	**0**
10. The directed problem solving sessions enhanced my learning experience.	**10**	**14**	**4**	**1**	**0**
11. I enjoyed interacting with my peers during the directed problem solving sessions.	**12**	**12**	**4**	**1**	**0**
12. I feel that most of the other students enjoyed learning in the directed problem solving format.	**2**	**16**	**11**	**0**	**0**
13. The on-line lecture enhanced my learning experience.	**6**	**11**	**7**	**4**	**1**
14. The on-line lecture prepared me for the directed problem solving sessions.	**2**	**16**	**6**	**4**	**1**
15. I viewed the on-line lecture before participating in the directed problem solving sessions.	**9**	**13**	**4**	**3**	**0**

Table 11. Survey Results for Junior-Level Trial 3, Fall 2006 (Traditional Lecture, N=36).

Question	*SA*	*A*	*N*	*D*	*SD*
1. I chose the traditional lecture option by default (or, because that was the division to which I was automatically assigned).	**10**	**11**	**2**	**9**	**4**
2. I would have chosen the directed problem solving/virtual lecture format if *that* had been the default option.	**1**	**7**	**9**	**14**	**5**
3. I was glad that I had a choice between two different course delivery options.	**8**	**18**	**8**	**1**	**1**
4. I used the on-line lectures *in addition to* attending the "live" class lectures.	**11**	**20**	**0**	**3**	**2**
5. I used the on-line lectures *instead of attending* the "live" class lectures.	**1**	**4**	**2**	**13**	**16**
6. The *Lecture Workbook* class note format helped me learn the course material.	**10**	**15**	**3**	**7**	**1**
7. I would prefer that the class notes *(Lecture Workbook)* be "filled in" rather than having to fill in the blanks during lecture.	**13**	**8**	**8**	**4**	**3**
8. I feel that I learn course material better in a traditional live lecture format than in a "virtual" (on-line) lecture format.	**4**	**10**	**14**	**6**	**2**
9. I would *not* consider taking *any* ECE course in a directed problem solving format.	**0**	**0**	**10**	**19**	**7**
10. Having a choice of course delivery options enhanced my ability to learn.	**5**	**14**	**13**	**1**	**1**
11. I took advantage of most of the on-line learning resources available for this course.	**12**	**18**	**2**	**1**	**1**
12. The practice homework sets and solutions helped me learn the course material.	**13**	**13**	**4**	**4**	**0**
13. The practice exams and solutions helped me learn the course material.	**19**	**12**	**2**	**1**	**0**
14. The modular, on-line ("virtual") lectures helped me learn the course material.	**12**	**17**	**3**	**0**	**2**
15. The on-line reference documents helped me learn the course material.	**7**	**21**	**3**	**2**	**1**
16. This course should *only* be offered in a traditional lecture format.	**0**	**1**	**11**	**16**	**6**

Table 12. Survey Results for Junior-Level Trial 3, Fall 2006 (Directed Problem Solving, N=31).

Question	*SA*	*A*	*N*	*D*	*SD*
1. The on-line lecture and directed problem solving session combination helped me learn the material better.	**8**	**17**	**2**	**4**	**0**
2. The on-line lecture and directed problem solving session combination helped me prepare for the *short answer and analysis questions* on exams.	**8**	**13**	**6**	**3**	**1**
3. The on-line lecture and directed problem solving session combination helped me prepare for the *programming questions* on exams.	**7**	**12**	**5**	**7**	**0**
4. The on-line lecture and directed problem solving session combination helped me prepare for the *laboratory experiments.*	**9**	**11**	**7**	**4**	**0**
5. I would choose the on-line lecture and directed problem solving session combination in another ECE course (if available).	**8**	**16**	**1**	**5**	**1**
6. I would prefer *only a live (traditional) lecture* over the on-line lecture and directed problem solving session combination for this course.	**2**	**4**	**4**	**16**	**5**
7. I would prefer a *live lecture and directed problem solving combination* for this course.	**7**	**13**	**4**	**6**	**1**
8. I enjoyed learning course material in the directed problem solving format.	**5**	**16**	**4**	**3**	**1**
9. I would prefer taking other courses with the directed problem solving format.	**3**	**18**	**5**	**1**	**2**
10. The directed problem solving sessions enhanced my learning experience.	**7**	**17**	**4**	**2**	**1**
11. I enjoyed interacting with my peers during the directed problem solving sessions.	**8**	**15**	**6**	**2**	**0**
12. I feel that most of the other students enjoyed learning in the directed problem solving format.	**3**	**16**	**11**	**1**	**0**
13. The on-line lecture enhanced my learning experience.	**6**	**16**	**5**	**2**	**2**
14. The on-line lecture prepared me for the directed problem solving sessions.	**4**	**17**	**6**	**3**	**1**
15. I viewed the on-line lecture before participating in the directed problem solving sessions.	**9**	**12**	**6**	**2**	**1**

Table 13. Survey Results for Sophomore-Level Trial, Fall 2006 (Traditional Lecture, N=68).

Question	*SA*	*A*	*N*	*D*	*SD*
1. I chose the traditional lecture option by default	**17**	**36**	**6**	**9**	**0**
2. I would have chosen the directed problem solving virtual lecture format if *that* had been the default option.	**12**	**27**	**16**	**13**	**0**
3. I was glad that I had a choice between two different course delivery options.	**13**	**26**	**27**	**2**	**0**
4. I used the on-line lectures *in addition to* attending the "live" class lectures.	**38**	**13**	**4**	**6**	**7**
5. I used the on-line lectures *instead of attending* the "live" class lectures.	**2**	**5**	**8**	**29**	**24**
6. The *Lecture Workbook* class note format helped me learn the course material.	**13**	**29**	**11**	**13**	**2**
7. I would prefer that the class notes *(Lecture Workbook)* be "filled in" rather than having to fill in the blanks during lecture.	**19**	**18**	**13**	**14**	**4**
8. I feel that I learn course material better in a traditional live lecture format than in a "virtual" (on-line) lecture format.	**2**	**18**	**21**	**22**	**5**
9. I would *not* consider taking *any* ECE course in a directed problem solving format.	**0**	**1**	**19**	**33**	**16**
10. Having a choice of course delivery options enhanced my ability to learn.	**3**	**32**	**27**	**4**	**1**
11. I took advantage of most of the on-line learning resources available for this course.	**24**	**37**	**5**	**2**	**0**
12. The practice homework sets and solutions helped me learn the course material.	**24**	**28**	**13**	**3**	**0**
13. The practice exams and solutions helped me learn the course material.	**35**	**27**	**2**	**2**	**2**
14. The modular, on-line ("virtual") lectures helped me learn the course material.	**31**	**19**	**15**	**1**	**2**
15. The *Index of Learning Styles Survey* helped me choose the course format best for me.	**0**	**11**	**34**	**22**	**1**
16. This course should *only* be offered in a traditional lecture format.	**0**	**1**	**18**	**30**	**19**

Table 14. Survey Results for Sophomore-Level Trial, Fall 2006 (Directed Problem Solving, N=25).

Question	*SA*	*A*	*N*	*D*	*SD*
1. The on-line lecture and directed problem solving session combination helped me learn the material better.	**12**	**12**	**0**	**1**	**0**
2. The on-line lecture and directed problem solving session combination helped me prepare for the *short answer (concept) questions* on exams.	**7**	**13**	**5**	**0**	**0**
3. The on-line lecture and directed problem solving session combination helped me prepare for the *written (application) questions* on exams.	**13**	**9**	**3**	**0**	**0**
4. The on-line lecture and directed problem solving session combination helped me prepare for the *laboratory experiments.*	**11**	**10**	**3**	**0**	**0**
5. I would choose the on-line lecture and directed problem solving session combination in another ECE course (if available).	**15**	**9**	**1**	**0**	**0**
6. I would prefer *only a live (traditional) lecture* over the on-line lecture and directed problem solving session combination for this course.	**1**	**2**	**2**	**12**	**8**
7. The *Index of Learning Styles Survey* helped me choose the course format best for me.	**1**	**13**	**6**	**4**	**1**
8. I enjoyed learning course material in the directed problem solving format.	**10**	**13**	**0**	**1**	**0**
9. Having a choice of course delivery options enhanced my ability to learn.	**9**	**12**	**2**	**1**	**0**
10. The directed problem solving sessions enhanced my learning experience.	**10**	**14**	**9**	**0**	**1**
11. I enjoyed interacting with my peers during the directed problem solving sessions.	**12**	**8**	**3**	**2**	**0**
12. I feel that most of the other students enjoyed learning in the directed problem solving format.	**5**	**16**	**4**	**0**	**0**
13. The on-line lecture enhanced my learning experience.	**13**	**10**	**1**	**1**	**0**
14. The on-line lecture prepared me for the directed problem solving sessions.	**13**	**9**	**3**	**0**	**0**
15. I viewed the on-line lecture before participating in the directed problem solving sessions.	**5**	**11**	**6**	**3**	**0**